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RURAL POPULATION MOVEMENTS

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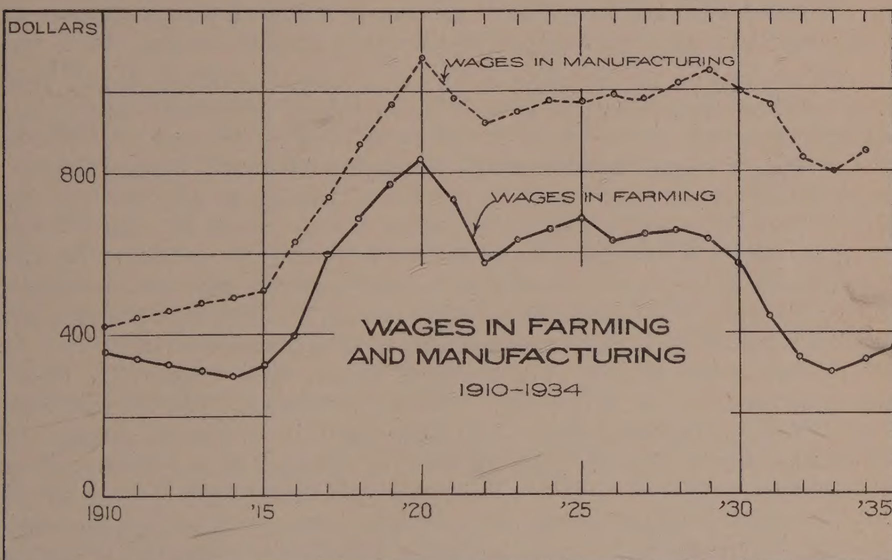
INTRODUCTION

The chart presented gives the figures of yearly earnings of those engaged in farming and in manufacturing from 1910 to 1934. The data are from the Dominion Bureau of Statistics; wages in manufacturing as recorded in the Canada Year Books and farm wages from the Monthly Bulletin of Agricultural Statistics. The latter are estimates, and absolute accuracy is not expected. The relative accuracy of these estimates is the important point as it is the position from year to year to which attention is directed. From 1910 to 1915 yearly figures are not available, nor the exact figure for wages in manufacturing in 1916, so the first comparison may be only for the five-year period. From 1917 to 1934 records are annual.



In 1910 yearly farm wages, including the value of board, amounted to 83% of yearly earnings in manufacturing. By 1915 the proportion was 67%. In 1919 it was 83% and in 1922, it was 63%. Two years later it was 66%. From 1924 to 1930 the proportion declined from 66 to 60%. From 1930 to 1934 it declined from 60 to 40%. During the four years from 1931 to 1934 inclusive the proportion averaged slightly less than 42%.

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Wages in manufacturing may be taken as somewhat typical of industrial wages. They are selected for this comparison for two reasons: one is their availability, and the other is the fact that manufacturing is partly the making of farm equipment and the processing of raw materials provided by farming. The latter point makes clear the indication from the record that when the proportion of farm wages falls below half the amount prevailing in manufacturing there is liable to be unemployment among workers in the latter field. Another question arises from this consideration as to the need to restrict interest in the export market chiefly to raw materials. If this is necessary, fewer employees will be required working up raw products. Another method of meeting the problem frequently recommended is the increased working up of raw materials on the farm by the extension of handicrafts.

Another revelation from the records is that the decline in proportion did not occur only during depressions. True, the greatest widening of the proportion took place in the depressions of 1920 to 1923 and 1929 to 1934; yet it also increased between 1924 and 1929, a period which has not recently been termed one of bad times. Between 1910 and 1934 the proportion of farm wages to wages in manufacturing dropped from 83 to 40 per cent. In 1933 the proportion was 41, showing, as the chart illustrates, that in the recent upturn wages in manufacturing have advanced more rapidly than have farm wages. It is suggested that when figures for 1935 and 1936 are available it will be found that the proportion of farm wages to wages in manufacturing will have declined still further.

This brings up the question of why this trend has taken place. It is fairly obvious that collective bargaining of labour in industry generally, outside of farming, has not only increased wages but also prevented declines. History may in some degree repeat itself in this particular. Some centuries since, the merchant guilds and craft guilds of Europe monopolized trades and professions to such a degree that some towns were depopulated when the domestic or handicraft stage superceded the guild system. At the beginning of the industrial system which followed the domestic or handicraft stage, James Watt, prevented from joining a craft guild, pursued his research work under the protection of the, at that time, peculiarly unorthodox thinker, Adam Smith. The power of steam, thus of somewhat illegitimate birth, gave the industrial system an advantage over the domestic or handicraft period and revived manufacturing in centres of population previously largely carried on by those who farmed as a sideline. Had steam power remained supreme, this advantage might have been retained and large centres of population have been still necessary as well as entertaining. But with the provision of electric power, sometimes by the public and in some sections less expensive than in others according to contracts entered into, carried out or cancelled, there is not now the necessity of the centralization of industry which prevailed when steam was more generally the source of power. Wide distribution of electric power should make a combination of farming and manufacturing more feasible now than prevailed in the domestic or handicraft stage. The greater the discrepancy between wages in farming and wages in manufacturing and industry generally, the less trade can occur between the two groups and the greater the proportion of manufacturing which will be done on the farm. The

widely heralded and warmly recommended decentralization of industry may eventually take place to some degree.

Thus we have the trend in population at the moment not toward the most profitable industries, as the classical economists suggested, but toward the subsistence farm as an alternative to unemployment. Confronted with this peculiar position, some study might be given to the problem of what was the greatest achievement of Adam Smith, writing *The Wealth of Nations* or protecting Watt and thus making steam power possible; or if you wish to put it another way, which rendered the greatest injury, the insistence on the efficacy of self-interest, or the provision of power which enabled industrial labour to concentrate, combine, collectively bargain and thus skim the cream from agriculture. Such a speculation might be a good thesis for a Ph.D. degree.

POPULATION AND NATURAL RESOURCES

With this introduction we may now proceed with the subject assigned, probably the most important subject which the economist ever confronts, namely the proportion of population to natural resources. It has occurred to me that the economics of agriculture had to do chiefly with how all people lived and by what means that living was secured. That appears sufficiently wide to offer scope for the most ambitious, but those responsible for arranging this programme and this topic now have added the idea of population, which implies how numerous people are and how these numbers are liable to change.

Indeed a superficial glance at the writings of economists specializing in agricultural problems, including presidential addresses, which are perhaps more volitional than this assignment, reflects the importance attached to the question of population. Increased attention is given to this point at the moment, no doubt on account of the general acceptance of the belief that power exists to provide plenty if only it is suitably directed. This stage represents a definite change from the fear of scarcity, particularly of food, which characterized the previous century. The larger problems of population shall of necessity have to be left strictly alone or treated briefly while concentrating on the possibility of securing a more satisfactory distribution of labour in different industries.

The possibility of a dense population engaged chiefly in farming, such as prevails in oriental, tropical and some southern European countries, is out of the question for Canada for two chief reasons. These are, first, that the standard of living demanded by the people will not allow it, and, second, the climate is decidedly against it. The population now living in Canada has been established chiefly on furnishing the export market with raw or semi-manufactured materials. Distance from market means low prices for raw products. Low prices combined with a high standard of living necessitate extensive methods, high production per man, and sparse population. Yet with such foundation there is some possibility of varying the number employed according to the organization of the industry.

It is generally conceded that there now are quite as many Indians in the country as when it was discovered or rediscovered in the fifteenth century. Yet at that time some controversy was carried on for possession

of hunting ground. The struggle for land appeared to be then quite as acute as at the present time. In the interval there was a frontier available and more or less alluring, ready to absorb not only the unemployed from industrial occupations but also a stream of immigrants sometimes of huge proportions. It was found, in the endeavor to provide land for returned soldiers, that the frontier no longer furnished relief for those not otherwise engaged. Hence the stream of immigration has become only a trickle, attention has been directed to closer settlement, and some attention recently given to what is termed subsistence farming. Yet even those who are the most hopeful of subsistence farming are careful to point out that for every farm family established there will be at least two other families required to cater to their needs.

In the meantime industries other than agriculture have made enormous strides, particularly during the present century and notably since 1910. These include besides making machinery for agriculture, transporting, and processing farm products, such industries as mining and providing newsprint. The lumbering and mining industries provide markets, sometimes temporary it is true, for farm products in some of the most out-of-the-way places. Farms spring up to serve local needs. The temporary nature of these markets, where some who come to mine remain to farm, sometimes provides perplexing problems, even suggesting that some farms have been improved in the wrong place. Such problems suggest the need for the closest possible co-ordination of the lumbering and farming industries in a climate such as prevails in Eastern Canada. This condition also accounts for considerable shift in rural population in a province with the natural resources of that of Quebec.

In the decade from 1921 to 1931 the population of Quebec increased in round numbers 513,000, or by 22%. The urban population increased 37% and that part termed rural 2%. Those gainfully employed in farming increased 3%. The division between rural population and those engaged in farming has never been definite until the last census, when this division was made, and in the province of Quebec it was found that 30% of the rural population was not engaged in farming. From this it may be noted that it is possible to increase the rural population without increasing the number engaged in farming. If the number engaged in farming increased by 3% and the rural population by only 2%, then the question may not be the desertion of the farm so much as the desertion of the village. Have teachers, doctors, dentists and clergymen clung any more tenaciously to the rural parts than the farmer? Montreal city not so many years since was credited with manufacturing some ten million pounds of butter in one year and is now down to less than three, while York County, including Toronto, is still credited with the production of some eight million pounds annually. There would appear to be some scope for decentralizing industries which never should have been centralized to the extent that has recently taken place.

It is possible to increase rural population without adding to number of farms. The population of Isle Perrot, Quebec, increased from 1921 to 1931 by 26%, the area occupied remained about constant, the improved land increased 2% and the number of farms decreased by 10%, expanding the improved area per farm from 75 to 90 acres in the interval. This is

by no means a typical case, as proximity to Montreal may be regarded as a major influence here; yet it reveals how some population movements may occur.

Sixteen Quebec counties recorded a decrease in total population during the decade. These counties included some of the best farming areas, but they included in 1931 no cities and no towns with over four thousand people, two between three and four thousand, and three between two and three thousand. These counties were among the earlier settled.

During the decade 27 counties recorded a decline in rural population. The other 29 recorded a sufficiently greater increase to make up the total increase already mentioned. The counties recording the decrease in rural population are generally the older settled and best farmed counties, where farms have increased in area with improved technique, and fewer workers are employed. The area worked per man for the province declined from 41 acres in 1921 to 39.5 in 1931. With one worker in agriculture for every forty acres of improved land where hay occupies the bulk of the area, it appears somewhat hazardous to suggest that there is room for more labour unless and until the type of farming is radically changed.

There is a vast difference in labour requirements on a farm after it is once improved as compared with the time when clearing is taking place. And one reason for abundance of labour is that permanently settled and improved rural areas, employing modern methods, provide a surplus of labour available for urban centres or the colonization of other areas.

Examination of the movements of population county by county in the province of Quebec during the decade from 1921 to 1931 shows two movements proceeding simultaneously. There is the absorption of surplus labour from the farm by industry and at the same time the shift from one farm area to another. Search for improved conditions appears ample reason for these movements. Judging from the condition reported in 1931 the movement may continue, as no great degree of uniformity of conditions in the industry of farming in the different counties has been yet attained as the gross returns per farm for the year 1930 reveal.

QUEBEC 1930–1931

Farm classification according to improved area	No. of counties	No. of farms	Gross returns per farm 1930
			$
50 acres and less	9	20,476	1,093
51 to 60 acres	7	14,820	1,275
61 to 70 acres	15	40,258	1,309
71 to 80 acres	22	43,110	1,465
81 to 90 acres	8	10,690	1,620
91 acres and over	5	6,612	1.560

This table presents only part of the picture; yet it indicates that in some sections production per farm and per man may yet be expanded with the consequent release of workers for other jobs or other sections. This movement has been proceeding elsewhere and may be expected to continue in spite of the temporary check which the past few years may have recorded.

In the United States the net movement of population from farms averaged 630,000 from 1920 to 1929. From 1930 to 1932 the net movement was in the opposite direction and for the three years averaged 255,000. In 1933 and 1934 the net movement was again away from the farm[3]. In the year 1932 the net movement to farms was over half a million. It is nowhere suggested by students of this subject that the extra number was needed in farming. It has been explained as occurring through lack of opportunity elsewhere. From 1920 to 1934 the surplus labour drawn from the farm by industry in the United States amounted to a total of six million, or 400,000 annually.

IMMIGRATION

One of the greatest wastes in training and experience is a system where many young farmers, after becoming masters of the craft, adopt some other calling. In so far as the industry can carry on without such experienced men there may be nothing to worry about, but when their places are taken by inexperienced men the industry suffers and those looked to for direction have a harder job. For this reason a more logical method of maintaining an effective balance in working population than any back-to-the-land movement would be a stay-on-the-land program. This would be feasible if reward for effort in farming compared favourably with that in other occupations. The fact that this comparison is not favorable explains why increased employment in farming has accomplished so little in reducing the number on relief.

During the past decade an endeavor was made to increase population by expansion of farming. The result was an increase, in round numbers, of 17,000 farms and less than 100,000 farm workers. During that time other vocations increased at a more rapid rate, but total population did not increase very rapidly, the net result being a shift of Canadians to industrial centres in the United States to be replaced by expensive importations from overseas. Expensive, as during that decade expenditures on immigration amounted to nearly twenty-four million dollars out of a total since the establishment of the country of fifty-nine million dollars. The objective during the decade was to expand agriculture. As far as immigration was concerned no expense was spared. Were the expenses of immigration charged to the increase in farm workers, which would not be unreasonable as those were the ones sought for during the period, then the 88,000 secured to this industry cost two hundred and seventy dollars each. The result during this time was a replacement of Canadians seeking better opportunities elsewhere by immigrants brought in at considerable expense to the public. Such a shift in the nationality of the people in the farming industry, which is still fortunately largely native born, could not take place without serious misgivings on the part of all interested in the industry.

Perhaps the most questionable policy of all has been that in the past it has been assumed that anyone should be able to farm anywhere successfully. And if failures ever occurred it was the human factor that was to blame. Hence if a farm was abandoned by one individual it was entirely the fault of the operator; it just could not be the environment—in the most attractive section of the world and varied as our conditions are,

[3] U.S.D.A. Bureau of Agricultural Economics, Farm Population Estimates; released May 2, 1935.

each and every county or precinct is persuaded that it is the most desirable as a farming prospect. Recently a change has taken place in this respect. Progress has been marked, until to-day in the province of Quebec it is put right squarely to the county agronomes at to whether or not in their opinion an abandoned farm should be resettled.

Since 1931 conditions have altered in several ways. First, industrial occupations are not so attractive at home or elsewhere. Second, mechanization of farming has been at least temporarily suspended in some degree. Farm power is again being derived from oats rather than oil. As a horse requires considerable care and labour and about two and a half acres to furnish its food supply, there may well be, as has been suggested, many additional workers added to the farming business since 1931. The decline in field crop area coincident with an expansion of production of live stock and live stock products might account not only for considerable increase in employment in farming but also, in co-operation with the weatherman and the regulations of many countries, the increase in prices recently occurring.

This automatic and necessary readjustment may be expected to be only temporary. With improved conditions in agriculture, urban industry revives and will again drain off the surplus labour from rural sections. The natural resources of Canada will not afford to farmers a self-sufficing and at the same time satisfactory standard of living. It is essential to continue to develop commercialized farming in the greater part of this extensive country. The comparatively short growing season necessitates it, were no other reason existent. Commercialized farming means an effective balance of prices and returns in different vocations—effective in allowing trade to take place and employment to prevail. This is necessary to prevent the over-development of sectionalism. A certain amount of pride of place is perhaps necessary and advantageous. Yet when this spirit is developed to such a degree as to threaten unification we may term it overdevelopment.

On account of the distribution of natural resources, which vary in different districts almost as much as the precipitation, various sections of the country have specialized along different lines. Consequently vocations vary in different sections. If and when some industries are for any length of time more prosperous than others for any reason whatever, then it follows that the effect will be a very uneven distribution of the reward of effort in different sections of the country.

The 1931 occupational record shows the following provincial distribution of the total workers and those engaged in farming.

	Total gainfully employed	Employed in farming	Proportion to total %
Canada	3,924,533	1,127,767	29
Prince Edward Island	32,168	18,382	60
Nova Scotia	181,083	43,931	24
New Brunswick	140,023	46,275	33
Quebec	1,022,739	229,208	22
Ontario	1,346,419	303,565	23
Manitoba	270,690	93,262	34
Saskatchewan	338,923	204,426	60
Alberta	286,218	145,663	50
British Columbia	306,270	43.055	14

In 1931 some 29% of the gainfully employed in Canada were engaged in farming. The proportion varies greatly in different provinces, from 14% in British Columbia to 60% for both Saskatchewan and Prince Edward Island. When such wide variation exists provincially and the larger area of some provinces is considered, the greater variation in smaller than provincial divisions will be readily understood. This specialization in different occupations and in the production of various farm products reveals the importance of trade and transportation not only between food-producing areas and large centres of population but also between various groups of farmers.

BALANCE OF POPULATION

Much is being written about a desirable balance of population. Just what constitutes a desirable balance might upon enquiry produce as many different opinions as the number considering the subject. The term effective balance has been used. By this we mean effective in giving as many as possible a job, as the greatest problem now connected with population movements is to overcome as far as possible the problem of unemployment.

If the proportion of population between farming and industry is out of balance in Canada, where is this the most pronounced? The proportion varies provincially from 14 to 60%. Those who claim that the numbers are out of balance must have some idea as to what the proportion should be. It is scarcely likely that any preconceived idea as to what this balance should be would lie outside this range. Then all that is necessary is to settle upon this proportion and look up this provincial table to find the location of such desirable conditions. Such procedure would reveal that effective balance for the whole country is the aim. To ensure this, all vocations must enjoy somewhere near the same measure of prosperity and purchasing power. Failing this, sectionalism will be overdeveloped and unification threatened.

If the balance between workers in farming and in other lines varies from 14 to 60%, in various provinces, and if ideas on what constitutes a desirable balance are so far apart, then it might be worth while to examine what specialists are doing the best with the aim of understanding the unrest demonstrating itself sectionally. Some studies of this nature have been made for both the extreme eastern and western provinces. The general conclusion of these studies has been that the central provinces, where industries other than farming are principally located, have been the most prosperous during recent years. Further studies along this line may be useful. Useful—as they would emphasise the need for a more effective balance of population between farming and industry in the different sections of the country. Such studies might indicate the necessity of the expansion of farming as far as possible in deficit areas of some food products such as British Columbia, Ontario, Quebec and Nova Scotia, and at the same time the development of manufacturing, especially the processing of farm products, in the provinces of Alberta and Saskatchewan where a large surplus of some lines of food products is provided. The expansion of bacon curing in the Prairie Provinces and the decline in numbers of live hogs shipped east reveals how progress is now being made long this line.

Investigation of the proportion of workers between industry and agriculture in the different sections of the country indicates the need for a fairly close relationship between the purchasing power of all different groups to ensure regular employment. When this relationship is strained to the breaking point, sectional unrest is marked, sectional self-sufficiency develops, and unemployment is increased. Further investigation, which is warranted, would probably indicate that sections where the workers are chiefly engaged in farming are not necessarily in the worst position. Though wages may be low, jobs are still available in this line. The rate of wages may be low but the regularity of work is greater.

WORKERS IN MANUFACTURING

	Number	Yearly earnings		Number	Yearly earnings
		$			$
1929	597,827	1,045	1932	400,328	852
1930	551,496	1,001	1933	399,409	785
1931	457,628	957	1934	445,432	837

From 1929 to 1932 yearly earnings in manufacturing decreased by 19%. That is only part of the picture, however, as during that time the number of workers on wages decreased by 33%. And manufacturing has been fairly busy during the depression compared with some others such as the construction industry, where the value of contracts declined from five hundred and seventy-seven million dollars in 1929 to ninety-seven million dollars in 1932, a drop to about one-sixth of the business of the earlier year. Steam railway transportation records yield the following results:

	No. of employees	Average salaries and wages		No. of employees	Average salaries and wages
		$			$
1929	187,846	1,548	1932	132,678	1,365
1930	174,485	1,538	1933	121,923	1,299
1931	154,569	1,485			

From 1929 to 1933 average earnings of employees dropped from \$1,548 to \$1,299, or by 16%, while number of employees declined from 187,846 to 121,923, or by 35%. In the meantime, as has been suggested, the number of workers in farming has increased, though we have not the exact figures since 1931.

CONCLUSION

All these results indicate that the chief cause of unemployment is high wage rates—a fact largely evaded for the past six years. They also explain why some of those not otherwise engaged enter *not* the most prosperous occupation, as was suggested by the comfortable doctrine of the

classical economists, but enter the possible occupation of farming where though wages may be low business still continues.

If a high rate of wages is the chief cause of unemployment, some of our workers who have so successfully collectively bargained themselves out of a job, have yet a choice between a lower rate of wages, which might yield greater yearly earnings to more employees, and seeking relief at the expense of the taxpayer. The move that is made either voluntarily or by compulsion, and if it is not done voluntarily probably some compulsion will be resorted to, is probably the greatest present problem in the movement of population.

WARBLE FLY CONTROL IN CANADA

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INTRODUCTION

During the past ten years the livestock and dairy industries in the Dominion of Canada have become increasingly aware of the extent of injury and loss caused by the two widespread species of warbles, *Hypoderma lineatum* DeVillers, and *H. bovis* DeGeer, and of the methods and feasibility of controlling them. Investigations carried out by the Entomological Branch, of the Dominion Department of Agriculture, and extension work of provincial Departments of Agriculture, and of various municipalities, have demonstrated the value of properly organized control campaigns, and of the effectiveness of derris washes when systematically applied. This work received marked impetus by the publication, in May, 1932, of Dominion Department of Agriculture Pamphlet No. 147, N.S., entitled "Warble Flies and Their Control in Canada", by Eric Hearle. Considerable publicity has also been given to the matter in the general agricultural press, and a bulletin prepared on the subject by the Ontario Department of Agriculture in 1930 was widely distributed in that province. The organized application of control measures in the Dominion as a whole is still somewhat limited in scope and extent, but definite progress has been made, particularly in Ontario, and certain parts of southern Quebec and British Columbia.

ECONOMIC IMPORTANCE, LIFE-HISTORY AND CONTROL OF WARBLE FLIES

Warble flies are injurious to cattle in several ways; during fly time the adult flies, while egg-laying, cause the cattle to run, reducing the milk yield and causing loss of flesh and condition; damage is occasioned to the hides by the grubs[3]; the animals become unthrifty and do not gain satisfactorily when the grubs are numerous, and wastage of valuable meat is necessitated through butchers having to trim off "licked beef" from the best parts of the carcass where the grubs have been. Losses from all causes attributable to warble flies in Canada have been estimated at from $7,000,000 to $14,000,000 annually.

The life-histories and habits of the two species are similar. The flies lay eggs during sunny days on the legs and lower parts of the animal. About 400 eggs are laid by each female. The tiny grubs hatch in a few days, penetrate the skin, migrate through the tissues, and, in some cases, congregate in the region of the gullet where they remain until late winter. They then migrate to the skin of the back, which they perforate to make breathing holes, and after about two months, force their way through the holes, drop to the ground, and change into pupae. From the latter, the flies emerge in spring and summer, mate, and lay their eggs. The flies live only a few days, but are continually replaced by the emergence of new individuals throughout the summer. They do not fly far.

[1] Dominion Entomologist.

[2] Assistant Entomologist.

[3] Hadwen, in 1912 (Dom. Dept. Agr. Bull. No. 16), estimated from statistics collected from tanners and hide dealers that the annual loss to hides through warbles in Canada was between 25 and 30 per cent

Control is effected by removing or killing the grubs while they are exposed in the backs of the animals. The simplest and most effective method consists of applying a wash made from standardised derris powder (1 lb.), soft soap ($\frac{1}{4}$ lb.) and water (1 gallon). The soft soap is boiled in a quart of water and when somewhat cooled is poured into a bucket containing the derris powder and mixed with it into a paste. Cold water is added slowly, while stirring, to make up one gallon; the mixture is then ready for use. Standardised derris warble fly powders ready for use are sold commercially. The cost of materials for four dressings is from 4–6 cents per animal. The date for the first application, varying in different parts of the Dominion, is in early spring when the swellings in the backs of the animals caused by the grubs first become conspicuous. In the interior of British Columbia this treatment is given in mid-February; in the Prairie Provinces and Eastern Canada, about the third week in March. The second and third applications are made after intervals of 28 days, and the fourth after a further interval of about 35 days. The wash is liberally applied to the backs of the animals with a cloth or brush wherever the grubs are present. Only sufficient wash for immediate application should be prepared, and it should be stirred frequently.

The effectiveness of these control measures against warbles has been recognized in other parts of the world as well as in Canada. In Great Britain an order of the Ministry of Agriculture and Fisheries, entitled "Warble Fly (Dressing of Cattle) Order of 1936", dated January 31, 1936, requires that every person (England, Wales and Scotland) having in his possession, or in his charge, any cattle which are visibly infested with the maggot of the warble fly, shall take prescribed measures consisting of either applying a derris dressing at proper intervals, or of squeezing out and destroying the grubs.

The Dominion Department of Agriculture is co-operating with the British Government in connection with the above order by treating all cattle exported from Montreal to the British Isles during the months of February to June with a standardised derris wash, as recommended by the British Government, under the supervision of inspectors of the Health of Animals Branch.

STUDIES IN WESTERN CANADA

The studies of warble flies and their control in Western Canada were carried out largely under the direction of the late Eric Hearle[4], who was Assistant Entomologist, in charge of livestock insect investigations, at the Dominion Entomological Branch laboratory, Indian Head, Sask., and subsequently, at Kamloops, B.C.

The Prairie Provinces

A survey of the warble fly distribution and damage in the Prairie Provinces was carried out by Mr. Hearle, in 1927-28. During the spring of 1927, 360 warble grubs were secured from forty carefully selected locations in Saskatchewan. Identification of these grubs showed that both *Hypoderma lineatum* DeVillers and *H. bovis* DeGeer are prevalent throughout that province. Prior to this survey little information on the distribution and abundance of *H. bovis* in the Prairie Provinces was available. This species

[4] Obit. April 17, 1934.

was recorded for the first time in Canada by Hadwen[5], at Agassiz, B.C., in 1912. It is now known to be widely distributed and common throughout the Dominion.

The dates of appearance of the warble larvae in the backs of cattle in the Prairie Provinces was also ascertained during the 1927-28 period. This is one of the most important factors in connection with control operations against these insects. At Indian Head, grubs of *Hypoderma lineatum* DeVillers first made their appearance in the last week of January, but were very scarce at that time. Late February was the period during which they were noted in greatest numbers. By March 7, a comparatively small proportion had reached maturity, but, by April 14, very large numbers had dropped from the animals, and the majority of those remaining were fully matured. By May this species had disappeared entirely, and was replaced by *Hypoderma bovis* DeG.

In 1927-28, circular letters, and interviews with practically all of the hide dealers operating in the three Prairie Provinces, according to Eric Hearle, elicited the following figures regarding the percentage of hides received which were injured by warble grub holes: percentage of grubby hides in the three Prairie Provinces (grub season January to July, 1928) 48.5; Manitoba 31.2; Saskatchewan 66.8; Alberta 47.7. These figures were computed from general estimates obtained from the hide dealers. Figures from one of the most important Ontario firms dealing in western hides and making definite inspections follow:—

	%
All western hides during the grub season	41.4
All western hides during the whole year	25 to 30
January	20
February	35
March	60
April	70
May	60
June	30
July	15

In the experience of this and other firms operating in both Eastern and Western Canada, hides from the Western Provinces were much more grubby than those from the East. In 1932, Hearle stated[6] that 30% of all hides received throughout the year in Canada as a whole are grubby, and 50–60% are affected during the grub season from January to June.

Information obtained during the 1927-28 period, from the managers of several large firms of hide dealers in Western Canada, who had taken particular interest in the warble fly problem, indicated that they considered that the pest was first introduced (in the Prairie Provinces) from thirty to forty years previously, and that there had been a marked increase during the last twenty years, but particularly from about 1908 to 1924, when a peak had been reached. It was stated that since 1924 the percentage of grubby hides had remained fairly constant within the usual range of seasonal variations. Several of these men stated that about 1913, only 25% of the hides handled during the grubby season showed grub injury, whereas the percentage of injured hides in 1927-28 averaged 65%.

[5] Dom. Dept. of Agric. Bull. No. 16, p. 7.
[6] Dom. Dept. of Agric. Pamph. No. 147, N.S., p. 8.

British Columbia

In 1928, Eric Hearle, officer in charge of livestock insect investigations, was transferred from Indian Head, Sask., to Kamloops, B.C., where for several years studies on the warble fly problem were continued under his direction as a major project of this laboratory. Data were gathered as to the distribution of the two species in British Columbia; the amount of infestation in different districts, and the percentage of grubby hides received by dealers in the early part of the year, and financial losses occasioned; the amount of control work practised and the measures employed; the earliest dates of appearance of grubs in the backs of cattle in various districts. Tests of derris-soap-wash to ascertain its efficacy and feasibility under Canadian dairy farm conditions were also conducted.

Examination of a large number of grubs in coastal and interior districts, during the years 1928–1931, indicated that both species of warbles were widely distributed throughout the province, and probably in normal seasons are equally abundant. In some years, however, *Hypoderma lineatum* DeVillers is much more numerous than the larger, and later form.

To ascertain the amount of warble infestation with greater accuracy than was possible from hide returns, surveys were made by officers attached to the Kamloops, B.C., entomological laboratory, of dairy cattle at a number of points in the Lower Fraser valley, and at various locations in the interior of the province. Systematic and careful counts were made of the number of grubs in each animal examined. During February and March, 1930, 520 animals from thirty dairy farms at twenty-two different locations were examined. In the Lower Fraser valley, from February 18 to 22, the number of grubs averaged 2 per animal, with a maximum of 92 grubs in one cow. The percentage of animals infested with grubs was found to be 56.2. At interior points, in the Okanagan valley, Salmon Arm and Kamloops districts, from March 19 to 23, an average of 5.1 grubs was found per animal examined, 71% of the animals being infested.

In 1931, further counts, under Mr. Hearle's direction, were made with the following results: a large Holstein herd at Tranquille examined February 24–27, averaged 19.04 grubs per animal, maximum 74; at Kamloops, February 24–27, there was an average of 19.03 per animal in Holstein herds, and 2.7 in Jerseys; the average for all dairy cattle examined at Kamloops being 10.86 grubs per animal, with a maximum of 88 grubs in one cow. At Agassiz, B.C., in the last week of February, 1931, the average number of grubs was 12.8 per animal, the maximum being 85; at Chilliwack, B.C., the average was 8.3 grubs per animal, with a maximum of 30.

The managers of two large firms dealing in British Columbia hides, interviewed by Mr. Hearle in 1929, estimated that during the grub season, from January to May, from 50 to 60% of all hides received were grubby, and during the main grub period (February to April), 75% of hides were affected. Inspection figures for 1929, from one of the most important firms in the province, were, however, as follows:

January	40% hides grubby
February	50% hides grubby
March	40% hides grubby
April	30% hides grubby
May	10% hides grubby

As a result of his observations, Mr. Hearle estimated the losses from all causes due to warble flies, in British Columbia, to be at least a quarter of a million dollars annually.

About one-half of the farmers visited in British Columbia, from whom information was obtained, practised squeezing out of grubs from their dairy animals. In some cases this was done systematically, but on many farms efforts in this connection were evidently haphazard.

It has been noted that grubs first appear in the backs of cattle, in Saskatchewan, late in January, and are seldom numerous until February. A number of dairy farmers in British Columbia co-operated with the officers of the Kamloops laboratory, in the spring of 1930, in efforts to ascertain the period at which grubs first appear in different sections of that province. Reports were made on fifty dairy herds, at about a score of points extending from Vancouver Island to the Okanagan valley.

To summarize the data obtained: very few grubs were observed in December and, in general, they were first noted during the first and second week in January. Vancouver Island returns showed that the grubs may appear during the last week in December, and may be numerous by the first week in January, although in some localities they did not make an appearance until the middle of the month. In the Lower Fraser valley, the appearance of the grubs has been recorded, at Agassiz, as early as December 15. In the returns received from herd owners, in 1930, a few grubs were noted at Abbotsford, B.C., as early as December 17, but, in general, grubs were not observed until the first week in January, when they were very small and scarce. By the middle of January they were reported as being numerous and well advanced in some localities, as at Mount Lehman and at Agassiz, but in most localities they had not attained either size or abundance at that time. At interior points in British Columbia few grubs were noted until mid-January, although a few were observed as early as December 30, at Okanagan Landing, and cows at this place showed fairly heavy infestation by the third week of January. At Salmon Arm, B.C., grubs commenced to appear in the backs of cattle about January 10.

In March, 1932, twelve farms were visited in the Lower Fraser valley, by officers of the Kamloops laboratory, and several hundred dairy cattle were critically examined. The marked difference in infestation in the extreme coastal sections as compared with the western inland parts of the valley was very noticeable, as in a survey made in 1929. In general, infestation appeared to be much the same as in 1930 and 1931, the majority of cattle in the Agassiz-Chilliwack areas being infested, while a large proportion of those at Sea Island and Lulu Island, B.C., were free, or nearly so. At a farm at Essondale, one of the largest Holstein establishments in British Columbia, a puzzling condition was noted by R. Turner, who was conducting the investigation under Mr. Hearle's direction. There were nearly 350 dairy animals on the farm, 100 of these being dry cows and heifers that were running out in 1931, and the remainder milking cows that were turned out into an adjoining and, apparently, similar field. The milking animals were mainly free, or nearly free, of grubs, but the animals that were running out in 1931 (including some mature dry cows) were heavily infested, out of all proportion to what one would expect, even

allowing for the greater susceptibility of the heifers and the more prolonged exposure to fly attacks. A cursory examination revealed few grubs in animals that had been in the milking herd in 1931. As against this, seven mature dry cows running out, averaged 20.7 grubs each, with a maximum of 40 in one cow; and 8 heifers averaged 13.5 grubs each, with a maximum of 40 in one heifer. The superintendent of the farm stated that all the cows in the barn were sprayed with a pyrethrum-petroleum oil spray, care being taken to spray the legs and parts well forward at the sides of the body. Commencing in June, they were sprayed each day, the main reason for spraying being to check horn flies. The milking cows (those from the barn only) also had their feet dressed with tar to check foot rot that had been troublesome there. There would appear to be no reason to believe that either of these two measures could have had any marked effect on the reduction of warble grubs. Only a proportion of eggs are laid low down on the feet, and the spraying commenced too late, of course, to be a factor in egg laying (as far as *lineatum* was concerned), even admitting the doubtful supposition that spraying has any appreciable repellent value against warble flies.

Some observations were also made, in 1932, in connection with a warble control campaign undertaken in parts of the Lower Fraser valley, under the direction of a representative of the Livestock Welfare Association of Saskatoon. Some of the herds in the control block at Chilliwack supposed to have been treated with derris powder in connection with this campaign were visited by Mr. Turner, but it was found that arrangements for the treatment of all herds had not been completed. No accurate conclusions could, therefore, be drawn, since in some adjacent herds one man treated conscientiously, another not at all, and some only applied one wash. Counts of grubs showed conflicting results, and the figures indicated that the control demonstration had failed on account of incomplete co-operation among the cattle owners concerned. However, a number of men visited were very pleased with the good results obtained from derris wash. Others claimed that the derris powder was too expensive under conditions then prevailing.

A general survey of warble fly conditions in the more important and accessible dairy herds in the Kamloops district was made by T. K. Moilliet, of the Kamloops laboratory, during the period January 21 to March 8, 1932, a total of approximately 140 animals being examined. He reported that on January 21, 1932, the herds in the district had an average infestation of 2.8 grubs per head. By February 12, this had risen to 5.2, which was the peak of infestation, and by March 8 it had dropped once more to 2.8. During March and April, 1932, the grubs became less numerous, but there was much variance in this respect among the different herds. This survey was continued by Mr. Moilliet, in 1933.

A comparison of the figures obtained in both years is made in the following table, which gives some idea of the fluctuations that may be expected in the case of a number of scattered farms. It will be noted that although the January figures show a slight decrease in 1933, those for February, 1933, show a marked increase, which more than offsets the January figures.

TABLE 1

Herd	January 21, 1932			January 23, 1933		
	Number of cows	Number of grubs	Average number grubs	Number of cows	Number of grubs	Average number grubs
1	23	96	4.1	27	87	3.2
2	10	16	1.6	14	24	1.7
3	16	22	1.4	16	49	3.0
4	—	—	—	15	24	1.6
5	43	121	2.8	46	42	0.9
6	8	3	0.38	16	10	0.6
Totals for Kamloops district	100	258	2.6	134	236	1.8
Herd	**February 12, 1932**			**February 6, 1933**		
	Number of cows	Number of grubs	Average number grubs	Number of cows	Number of grubs	Average number grubs
1	18	200	11.1	31	301	9.7
2	10	36	3.6	14	88	6.3
3	16	15	1.0	18	131	7.3
4	16	38	2.5	15	33	2.2
5	40	218	5.4	46	206	4.5
6	16	4	0.25	16	30	1.8
Totals for Kamloops district	116	511	4.4	140	789	5.6

The most striking variation in the degree of grub infestation was noted in neighboring herds, in the Kamloops district, and data were collected with a view to ascertaining some reason for this, enquiries being made regarding the kind of hay fed, the amount of salt used, the type of drinking water, and the feeding of sulphur as a skin conditioner.

Infestation conditions on the respective farms in the spring of 1933, however, did not show much relation to those of 1932. Table 2 shows a comparison of five herds, from which it is evident that any one herd may

TABLE 2

Herd	Supposed peculiarity of feed	Percentage of infestation				
		1932		1933		
		Jan. 20	Feb. 12	Jan. 23	Jan. 30	Feb. 6
3	Salted alfalfa; plenty of salt	1.7	0.9	1.4	6.0	7.0
4		—	2.5	1.6	2.5	2.2
6	Well water with heavy iron and sulphur content	0.38	0.5	0.6	1.5	1.7
5	Also use of well water; not so strong	2.8	5.0	0.9	2.2	4.5

itself vary, from year to year, more than different herds. The only consistently low average of infestation was in herd No. 6, and its peculiarity of diet was the use of well water strong in iron and sulphur. However, these data are too meagre from which to draw definite conclusions.

CONTROL STUDIES IN BRITISH COLUMBIA

Preliminary tests with various forms of derris-soap wash were commenced at the Kamloops Entomological Branch laboratory, under the direction of Eric Hearle, during February and March, 1931, with a view to ascertaining if this was a feasible and effective control measure under Canadian dairy farm conditions. Several herds in the Kamloops and Tranquille districts received treatment and the results were so satisfactory that the experiments were extended during subsequent years.

Dairy Cattle (1931–35)

This work was undertaken in the spring of 1931 to prove its value to the dairymen of the district and to gain their co-operation in applying control measures.

Herds at Tranquille and East Kamloops gave ideal conditions under which to work; the former consisting of pure-bred Holsteins, on a large scale, with up-to-date equipment; the latter a farm herd of mixed Jersey and Holstein grades. No ill effects followed any of the treatments.

The method employed in 1931, in treating the East Kamloops herd, which seemed to give the best results in that district, was to pour the derris wash from a bottle with one hand and to thoroughly rub it over the infested parts with the other. The wash was poured along the backs and rubbed down the sides as far as necessary. In some cases grubs were found far down and quite often in front of the withers. A few grubs were also sometimes found back of the hook bones or hips.

R. Turner, who carried out the work in 1931, reported that, in counting the grubs after treatment, he found difficulty in ascertaining whether or not they were dead, as in some cows the lumps did not decrease in size for a considerable time after the grubs had died; in others they disappeared quickly. Young grubs in small lumps disappeared within a few days, but old grubs in the late fifth stage and having tough skins remained for a long time, leaving a large lump on the hide. It was noted that live grubs were very much easier to squeeze out than dead ones. Often the posterior end of the dead late fifth-stage grubs when shrivelled would protrude from the warble hole, and could be drawn out by forceps or fingers. In Jerseys, the grubs could usually be squeezed out readily, owing to the more pliable skin of these animals.

The results in 1931 are summarized as follows: An inspection of 110 dairy cows (Holsteins and Jerseys) in herds at Tranquille and Kamloops, B.C., in late February, before any control treatments were applied showed that 88% were infested. The average number of grubs *(H. lineatum)* for all these cows was 10.86; for Holsteins 19.03, and for Jerseys 2.07. Four applications of derris wash to the animals in the Tranquille herd gave 100% kill. One gallon of wash containing one pound of derris powder was found to be ample to treat 16 heavy coated, badly infested animals. In cases of light infestation, more animals could be treated with this quantity.

During 1932, warble conditions in the dairy herd at Tranquille, B.C., were checked weekly from January 20 to February 18, by T. K. Moilliet. On the former date there was an average of 3.27 grubs per head. Infestation reached a peak of 5.31 on February 3, at which date some grubs were squeezed out to ascertain when it would be necessary to apply the first wash. This reduced the average to 5.2 on February 18. On this date the first derris wash (half strength) was applied to 54 infested animals of the 81 which comprised the herd. About one gallon was used, at a cost of 2.5 cents per head. There was a marked reduction of grubs following the treatment, and by March 16 there was less than one grub per head. On March 21, the second wash was applied to the dairy herd. In this case full-strength derris wash was used, and a check-up on April 11 showed a 100% kill. The cost of this treatment was also 2.5 cents per head. The average number of warbles in each animal was 2.6, or half as many as at the first treatment. As the infestation with *H. bovis*, during May and June, proved to be negligible, no further treatments were made. Since herds in the district which had not been treated still had many warbles, the absence of grubs at Tranquille was attributed to the last treatment.

During the 1933 season, Mr. Moilliet made observations on the warble conditions in the Tranquille dairy herd once every seven days (except February 11), to determine the period of greatest abundance, and the stage of growth of grubs, so that treatment could be made at the proper time. A number of grubs squeezed on February 4 were still white and fairly small, so it was decided that February 18 (the same date as in 1932) would be early enough for the first treatment. This proved to be correct, as no maturing grubs were taken in any of the herds until after February 25. During the first treatment, on February 18, the grubs were counted. The following table gives the results of the earlier counts and the count made at the time of treatment:

1933—January 21—1.0 grub per head.
January 28—1.8 grubs per head.
February 4—2.4 grubs per head.
February 18—Treated first time, and again on February 25.
March 11—1.5 live and dead grubs per head.
March 18—1.8 grubs per head.
March 25—0.6 grubs per head (March treatment made).

The additional treatment on February 25 was made because it was noted that some 20% of the grubs had survived the first treatment. It was thought possible that the derris powder used, being a year old, might have lost strength, so the next treatment (February 25) was made one and one-half times stronger than the recommended dosage. This resulted in a 100% kill. This mixture may be more efficient, as it is heavier, does not spill so easily, and can be placed on the cysts only, instead of running off down the sides of the animal.

The following table shows that in the dairy herd consisting of 53 head, the degree of infestation had been cut in half by the control measures of the preceding year. A comparison with the figures for the Kamloops local herds would show that, had it not been for control, an increase might have been expected in 1933.

TABLE 3

1932			1933		
Date	Number of grubs	Average	Date	Number of grubs	Average
Jan. 20	106	2.0	Jan. 21	45	0.8
Jan. 27	117	2.2	Jan. 28	94	1.7
Feb. 3	234	4.4	Feb. 4	110	2.0
Mar. 21	96	1.8	Mar. 18	54	1.0

In 1934, the first treatment of the dairy herd at Tranquille was made on February 23. In all 100 head were examined, 19 head of which were found infested and were treated. Good reductions over the 1933 figures were found in the cows, but the two-year-olds showed a slight increase over that year. This was the result of over-heating the derris wash in 1933. According to a report received from Mr. Hearle, it appears that when the temperature of the wash is above 110° F., the consistency changes, the powder is quickly precipitated, and there is apparently a loss of toxicity. This occurred when the yearlings were treated on March 4, 1933, and only a 20% kill resulted. The subsequent retreatment was apparently too late to destroy all the warbles. The fact that the progeny of these flies were almost entirely confined to the two-year-olds may be due to the longer period of exposure of the young stock. The two-year-olds had the least shade of any of the dairy cattle. The following summary gives the figures for the first 1934 treatment:

First Treatment of Tranquille Dairy Herd, February 23, 1934

Of 60 cows....................	12 head had 19 warbles
Of 15 two-year-olds..........	7 head had 68 warbles
Of 25 yearlings..............	0 head had 0 warbles
Of 100 cattle.................	19 head had 87 warbles

Average infestation—0.87 grubs per head.
Average for infested animals—4.6 grubs per head.

In this treatment $\frac{1}{4}$ lb. of standardized derris powder was mixed in $1\frac{1}{2}$ pints of water. In applying it, only the individual cysts were anointed by hand, the scabs being scratched off with the short finger nails and the wash carefully worked in. On this occasion the operator was occupied for only one hour.

The cost of the treatment was: 25¢ for derris and 25¢ for labour = 50¢ or $\frac{1}{2}$¢ per head.

A check-up made a week after this treatment revealed only 4 live grubs out of about 75 squeezed cysts, which would indicate an 82% kill from this treatment.

A comparison of the dairy herd infestation, at times of grubs counts and first treatment, is given at the left.

Date	Average number of grubs per head		
	1932	1933	1934
Jan. 22	3.25	1.0	0.0
Feb. 18	5.2	3.0	0.4
Feb. 23	—	2.0	0.8

It should be noted that the first maturing grubs were found after February 25, 1933, whereas in 1934 no maturing grubs had been found a week later than this.

The second treatment of the dairy herd in 1934 was made on March 23, exactly one month after the first. Only six live grubs were found on this occasion. No adult warble fly activity had been noted up to that date.

The observations were continued by T. K. Moilliet, of the Kamloops laboratory, in 1935, and he reported that no warble grubs could be found that year in the animals comprising the dairy herd. In Table 4 he has summarized the results from treating the dairy cattle at Tranquille, B.C., over the five-year period (1931–35). The counts in each year were made at the time of the first application of derris wash.

TABLE 4

Year	1931	1932	1933	1934	1935*
Date	Feb. 24	Feb. 18	Feb. 18	Feb. 23	
Number of cattle (mature cows only)	50	81	73	60	—
Number of cows infested	46	54	36	12	—
Percentage of cows infested	92%	67%	50%	20%	—
Total number of grubs	950	430	378	19	—
Average infestation per head	19	5.3	3.8	0.3	—
Average infestation of infested cows only	20	8	10	1.6	—

* No warbles were found in the dairy herd in 1935.

The figures in Table 4 clearly illustrate the effectiveness of derris wash in controlling warbles when it is properly and systematically applied over a period of years.

Beef Cattle (1932–35)

On February 18-19, 1932, the pure-bred cattle, bulls and calves, in the beef herd at Tranquille, B.C., were examined by T. K. Moilliet, and treated. Of these, 235 head were put through the chute and showed an average infestation of 2.0 grubs per head. Those infested were treated with a wash consisting of one-half pound of standardized derris powder to a gallon of water. On February 23, the main beef herd of 437 head was gone over, and showed an average of 4 grubs per head. These animals were treated with the same half-strength wash as above. The cost of treating the 672 animals was 3.5 cents per head. The second treatment of the beef herd was applied on March 31–April 1, while the animals were being dehorned. The correlation of the second wash with dehorning produced a substantial decrease in the cost of application. Since a good kill was doubtful in the case of the half-strength wash used in February, full-strength wash was used on this occasion, so that although the number of grubs was only one-half as many as in February, almost as much powder was used. The additional labour, however, amounted to $8.00, bringing the total cost to $13.00, an average of slightly less than 2 cents per head. It should be noted that although a large proportion of the cows were near calving, no

abortions resulted from their being treated. The butcher reported that in the steers he killed following this treatment a good kill of grubs had been made. Mr. Moilliet found it impossible to get accurate counts of the grub infestation, due to confusion between old and new cysts.

The control work in the Tranquille beef herd was continued by Mr. Moilliet, in 1933, in a manner similar to 1932. The cattle were brought back from the range to Tranquille during the second week in February, so that it was possible to make the treatments at the home corrals.

After some very cold weather during the period February 7–18, a thaw set in, and conditions became favourable for applying the derris wash to outside animals without fear of chilling. The range cattle and the pure-bred Herefords were put through the dehorning chute, February 22–24, examined for warbles, and those infested were treated with standardized derris-soap powder at the recommended strength of one pound to one gallon of wash. Table 5 shows a comparison of the 1933 figures obtained during the first treatment, with those obtained on the same date in 1932.

TABLE 5

Year	1932	1933
Date	Feb. 18-23	Feb. 23
Total number of cattle	672	732
Number of animals infested	399	205
Percentage of infestation	59%	28%
Total number of grubs	3,151	1,330
Average grubs per head	4.7	1.9
Average infestation of infested cattle only	7.9	6.6
Cost of labour	$16.00	$22.00
Cost of derris powder	5.75	4.00
Total cost	$21.75	$26.00
Cost per head	3.2c	3.5c

The effectiveness of the applications made in 1932 is indicated by the large reductions in the percentage of animals infested, and the total of grubs found.

The second treatment of the Hereford cattle at Tranquille, in 1933, was begun on March 20, when 25 old bulls, 8 young bulls and 149 range yearlings and calves were examined in the chute. The latter were also dehorned, branded and castrated where necessary. The following day the 63 pure-bred cows and heifers were examined, as well as the 41 head of prime steers. Treatment of the above required 1.6 gallons of derris wash costing $1.60. The cost of labour was taken as that of the extra help needed to put on the wash and to run some of the cattle through the chutes, which amounted to three men for one day, and one man for half a day, $7.00. The total cost of this treatment of 286 head was $8.60, an average of 3 cents per head. The second treatment was completed on March 28, with the main beef herd of 406 head of cows, steers and heifers. Grub counts obtained on this occasion showed an average infestation of 0.9 grubs per head, less than one-half those at the time of treatment in February. Mr. Moilliet stated that it was impossible to be sure whether live grubs or old cysts containing dead grubs were counted; but all suspicious cysts were treated. The proportion of the figures representing live grubs, however, would be about 30%, or 0.3 live grubs per head.

Table 6 gives the March grub counts, and approximate costs for the second treatment of the beef herd.

TABLE 6.—SECOND TREATMENT OF BEEF HERD, TRANQUILLE, MARCH, 1933

Section of herd	Date of treatment	Number of animals	Number of grubs	Average grubs	Number of infested animals	Percentage infested	Average grubs in infested animals	Costs
Old bulls	March 21	25	135	5.4	14	54	10.0	
Young bulls	March 21	8	64	8.0	5	62.5	13.0	Derris $ 1.60
Cows and heifers	March 21	63	99	1.5	36	57	2.5	Labour 3.00
Pure-bred herd—Totals		96	298	3.1	55	57	5.4	$ 4.60
Prime steers	March 21	41	55	1.3	13	32	4.2	
Yearlings and calves	March 20	149	43	0.3	6	4	7.1	Derris $ 1.50
Cows	March 28	280	109	0.4	37	13	2.9	Labour 10.00
Heifers	March 28	51	62	1.2	22	43	2.8	
Young	March 28	75	92	1.2	20	26.7	4.6	$11.50
Range herd totals		596	361	0.6	98	16	3.5	
Total for all beef animals		692	659	0.95	143	21	4.6	Total cost $16.10
								Cost per head 2.3c.

The discrepancy in the number of animals in these two treatments is accounted for by the fact that about 30 cows had calved by March 28, and it was impossible to bring them from the field for fear of the calves being hurt in the corrals. The other 10 head missing from the second count represent those butchered during the period February 23 to March 28. Table 7 gives a comparison of the first and second treatments for 1933. The cost was 2.3¢ per head in March as compared with 3.5¢ in February. This was because the March treatment was correlated with dehorning.

TABLE 7

Date	Feb. 23	Mar. 21–28
Total number of cattle	732	692
Number of infested animals	205	143
Percentage of infestation	28%	21%
Total number of grubs	1,330	659
Average grubs per head	1.9	0.95
Average for infested animals only	6.6	4.6

In 1934, the first treatment of the beef herd, at Tranquille, was applied on February 21–23, 752 head of cattle being examined and treated at a total cost of $16.00, or 2.1¢ per head. Of these, 114, or 15.2%, were infested with 695 grubs, or 6.1 per animal.

The second application in 1934 was begun on March 27 with the treatment of 164 head, of which five had only 14 grubs, many of which were maturing. On March 29, 182 yearlings were examined, nine of which had 28 grubs. On April 4-5, the remainder of the beef herd, fat steers and bulls, were examined and about 60 grubs treated. The management was loath to have them treated as calving had begun. However, much care was taken and "no calves were slipped". This danger is the principal deterrent to big cattle ranches undertaking control, though our officers have stated there should be no trouble if the cowboys treat the cows gently and slowly.

In 1935, 601 animals comprising the beef herd were examined for treatment. At the time of the first application of derris wash (February 28 to March 2), 245 of the cattle, or nearly 41%, showed infestation, and the cost per head of the treatment in this case was 4.1¢. The high percentage of infestation was unexpected, and was believed to be probably due, at least in part, to the fact that the animals had been allowed to run with untreated stock from other herds, after the 1934 applications. Another rather surprising feature is shown in Table 8: it is much more usual to find the heaviest infestation among the young stock.

TABLE 8

—	Number of animals examined	Number of warbles found
Yearling and mature beef stock	391	1,675
Young beef stock	176	271
Young and mature bulls	34	114

Figures for the second treatment of the beef herd in 1935, young stock only, are given below:

Number of animals examined.................... 176
Number of warbles found........................ 83

Number of warbles per head	0.47
Number of infested animals	18
Percentage of infestation	10.2%
Average grubs in infested animals only	4.6

The remaining animals in the herd were treated on April 4, but comparable figures were not recorded.

In Table 9 the figures obtained at the time of the first application of derris wash to the Tranquille beef herd during the four seasons, 1932–1935, are presented. The comparison has been made on the basis of the first treatment, since second treatment counts, owing to confusion between living grubs and those which had been killed by the first treatment might be misleading.

TABLE 9

Year	1932	1933	1934	1935
Total number of cattle	672	732	752	601
Number of infested animals	387	205	114	245
Percent of infestation	58%	28%	15%	41%
Total number of grubs	3,125	1,330	695	2,060
Average number of grubs per head	4.6	1.9	0.9	3.4
Average number per infested animal	8.1	6.6	6.1	8.4

As indicated previously, the comparatively high infestation in 1935 was probably partly due to the animals mixing with untreated stock subsequent to the 1934 treatments. This factor and the following are believed responsible for the increase in 1935, and also to some reinfestation in the previous years. The second factor was the leaving untreated of cows that had just calved, or were about to calve, a matter that could have been avoided by treating the animals in a pen, instead of forcing them through a chute. The experience of our officers in the Deep Creek, B.C., control project, discussed in the next section, showed that where these two factors are eliminated, complete eradication of warble infestation may be effected in three or four years. As already recorded, the Tranquille dairy herd was entirely free of warbles in 1935, after the systematic application of derris wash over a period of four years.

OTHER CONTROL PROJECTS IN BRITISH COLUMBIA

Another control project was incepted in 1933, when the officers of the Kamloops laboratory, in co-operation with the Livestock Branch of the Provincial Department of Agriculture, undertook warble control in the Deep Creek valley, near Salmon Arm, B.C. This valley is entered from a point about midway between Enderby and Salmon Arm. The control area runs southwest for about nine miles up Deep creek, to where there is a natural constriction of the valley which forms a good barrier to reinfestation. The elevation of the area is 1,800 feet, and the snowfall is therefore greater, and the temperatures lower, than in the surrounding districts. The width of the bottom of the valley varies from about half a mile to a mile, and the soil, like that of so many areas where irrigation is unnecessary due to heavy precipitation, is reported to lack lime and other minerals.

Table 10

—	Number of animals	Number of warbles	Average number of warbles
Bulls	15	11	0.73
Cows	223	432	1.0
Two-year olds	63	278	4.4
Yearlings	73	250	3.4
Calves	17	8	0.47
Totals	391	979	2.5

Organization for this project was effected by Mr. H. E. Waby, District Agriculturist at Salmon Arm, through the local Farmers' Institute. Standardized derris-soap powder was supplied by the Provincial Department of Agriculture.

The first treatment was applied February 10–14, 1933. Twenty-eight ranches were visited, and 391 cattle examined. All infested animals were treated with the derris-soap powder at the rate of one pound to the gallon of wash. The results of the survey are summarized in Table 10.

The second treatment was undertaken March 13–15, 1933. A total of 406 animals was examined, the average infestation per head being 4.6, as shown in Table 11.

Table 11

—	Number of animals	Number of warbles	Average number of warbles
Bulls	15	33	2.2
Cows	222	896	4.0
Two-year olds	63	388	6.2
Yearlings	71	399	5.6
Calves	35	111	3.2
Totals	406	1,847	4.6

In order to make a comparison with conditions at Salmon Arm, two herds one mile west of that town were examined on March 16. The 32 head inspected averaged 9 grubs per head, from which it would seem that warbles are more abundant in the immediate vicinity of the Shuswap lake (that is, at Salmon Arm) than they are in the relatively high and cold Deep Creek valley.

Figures for the first two treatments at Deep Creek, in 1934, reveal the effectiveness of the washes applied in 1933. At the time of the first treatment (February 11–14) in 1934, only 129 warbles were found in 406 animals; this should be compared with 979 warbles found in 391 animals at the same date in 1933. When the second treatment was applied (March 11–14), in 1934, the number of warbles was 199 as compared with 1,847 in 1933.

Figures for 1935 in connection with the Deep Creek project are not on hand, but T. K. Moilliet, of the Kamloops laboratory, reported in May, 1935, that almost complete control of warbles had been secured among the cattle in the valley.

In January, 1934, a control area was organized in the Upper Louis Creek valley involving about 500 cattle. Although no extensive figures are available from this area, one livestock owner reported in 1935 that his cattle showed almost complete elimination of the fly. Only eight grubs were found in his herd of cows about March 15, 1935. He reported that others had found the same scarcity of grubs. Nearly all of the cattle owners of the valley were whole-heartedly in favour of continuing control.

Another farmer, however, declined to have his cattle treated as he believed he lost a calf in 1934 owing to having the cattle worked before calving. According to Mr. Moilliet, the question of the advisability of treating cattle before calving is undoubtedly a factor adverse to warble control on large cattle ranches, although it is a difficulty that may be overcome by careful handling of the pregnant animals.

WARBLE CONTROL IN EASTERN CANADA

Ontario

The following statement on warble fly control in the Province of Ontario was prepared and submitted by Dr. Lionel Stevenson, Provincial Zoologist for Ontario:

"The loss caused to the animal industry by the two flies, *Hypoderma bovis* and *Hypoderma lineatum*, had long worried the more progressive cattle owners of Ontario. The estimated losses exceeded five million dollars per annum in 1930. The losses were listed as follows: injury to hides, reduction in dairy cattle output, a reduction in beef cattle output, unthrift in young cattle, lowering of health standard and body injury.

"From 1926 to 1932 an attempt was made to induce cattle owners to make a move toward controlling the warble fly pest. The press, the lecture platform, exhibitions and fairs, and other gatherings were used to reach the cattle owners with a message covering the life-history of the flies and the possibilities of control. Posters, damaged leather samples, and grub-killing equipment were placed in many schools, cheese factories, creameries, agricultural offices and other places frequented by farm people. A bulletin was prepared covering warble control fully, in 1930. Its distribution has been wide, reaching the majority of Ontario farm homes.

"The tanner's section of the Toronto Board of Trade arranged a conference of livestock men, packers, tanners and government representatives, with the hope of getting something underway that would result in improved hide conditions. This meeting was held during November, 1931. The interest aroused at this meeting was considerable and had much to do with the starting of the Barrie Island warble control work.

"The Barrie Island township warble control project got under way in March, 1932. A reduction of 23 to 0.66 in five years, under rough farm conditions. Butchers handling cattle from this area report backs clean and hides free from grub punctures during the past two seasons. Gadding ceased following the second season's work. Cattle have improved in condition.

WARBLE CLEAN-UP DEMONSTRATION, BARRIE ISLAND, ONT.

Year	Number of cattle	Number of grubs per animal
1932	832	23
1933	735	9.21
1934	783	4.7
1935	735	1.19
1936	704	0.66

"On Manitoulin island, 20,000 head of cattle were treated for two seasons, 1933 and 1934, under departmental aid and supervision. This

work on Manitoulin, well started, has slipped backward, due to indifference on the part of some cattle owners. In the spring of 1936, three townships declined to undertake further warble control as a municipal project, until enabling legislation is provided.

"The experience was the same on Scugog Island, in Ontario county, as it was on Manitoulin. On Scugog, 1,200 cattle were given treatment during 1933 and 1934. The reduction in warble infestation and general improvement of the cattle was marked. The better farmers in this area have continued the control work while the others have let the work slide along undone or half done. Legislation is needed to bring the indifferent up to the point of doing their share for the common good. The township council of Scugog, backed by the better farmers, sought enabling legislation following the first year's demonstration. Following the Scugog Island demonstration, owners of 30,000 head of cattle in Ontario county gave the warble larvae attention.

"Two of the most progressive counties in Ontario, Oxford and Elgin, undertook warble control in a big way, starting in 1934. Complete propaganda and an organization in which 200 leading farmers in each county aided, resulted in 125,000 head of cattle being treated. The county council paid for the costs of material used, and the work was directed from the office of the Ontario Department of Agriculture in the county. The work in these two counties was repeated without change of plan in 1935 and 1936. The work has been highly satisfactory to cattle owners in Elgin and Oxford, where dairy farming is the main industry.

"The cattle in the counties of Middlesex, Lambton, Bruce, and Wellington, have also received consideration during the past two years. The county council in each county voted the funds necessary to carry out the work, while the Agricultural Representative directed the organization and the propaganda. The improvement in these six counties has been highly satisfactory to cattle owners, the warble pest having disappeared from all farms where reasonable attention has been given to the control work by the owners of cattle themselves.

"The reports coming from all counties in Ontario show that over one million cattle were treated in the spring of 1935 and again in 1936. Ontario has a cattle population of nearly three million head. So the warble control work has reached but one third of the cattle to date. The improvement desired can not be attained until all cattle are treated for three or more years. The work has started but there is still a long way to go.

"The examination of large numbers of cattle in the Union Stock Yards during the warble season, March to June, indicated a considerable reduction of grubby backs and warble punctured hides, over past years.

All hide buyers and tanners report an improvement in the condition of hides from cattle coming from the areas where control work has been under way.

"Farmers reporting to Ontario Agricultural Representatives on the warble situation in their districts, express satisfaction over the improvement resulting from the reduction in warble flies. The gadding has stopped, and the cattle are producing better.

"The bringing in each year of thousands of warble grub-infested feeder cattle from the Western Provinces, to be distributed over the areas in Ontario where warble control has been undertaken, threatens to seriously interfere with all control work in this province. These untreated Western cattle, 150,000 in number each year, going on to Ontario farms, reinfest the areas. Many of the Western cattle are wild, and therefore difficult to treat without special holding equipment. These cattle are very likely to go untreated.

"The packer and the hide buyer have, in the past, paid too high a price for grubby hides and grubby backed cattle, in comparison with the price they paid for clean hides and cattle. When the difference in market price between high grade and low grade products is made wide enough, many producers now offering the low grade (grubby hides) will deem it worth while to improve their product by doing their part in warble control. This matter was considered by the packers and hide dealers at a meeting held in Toronto, November 29, 1935.

"The grub-injured hide is like the wormy apple; so long as there is a market for such low grade product, the indifferent farmer will produce it. It is up to those dealing in hides of cattle, to encourage high quality by paying a high price for it and to discourage the production of low quality hides by declining to trade in such. The practice of buying hides at a flat rate at country points (no grading) is discouraging to the farmer who is doing his part to control the warble pest. Good money for quality hides will help warble control."

Quebec

In 1933, N. A. Drummond, Provincial Agriculturist for Pontiac East, with the advice and assistance of officers of the Dominion and Provincial Departments of Agriculture, and the co-operation of the municipal authorities concerned, incepted a warble fly control project on Calumet island, on the Ottawa river. This island is about 50 square miles in area, with a population of some 1,300 people, including more than 150 cattle owners, with approximately 2,000 head of cattle. The island is separated from the mainland by a strip of water about one-quarter of a mile wide, and is well suited for a warble control demonstration owing to its insular character. To ensure that all cattle were treated, the municipal council passed a by-law to this effect, in 1933, and the work has been continued each year from 1933 to 1936. Three treatments with a standardised derris wash were given annually, with intervals of approximately four weeks between each treatment, the first one being applied about March 15–20. It was found that the best method of application consisted of using a stiff corn brush, since this removed the scabs, and so ensured that the material would reach the grubs and destroy them.

The adjoining table published (September 12, 1936) by Mr. Drummond, in the Journal of Agriculture of the Quebec Depart-

Year	Number of cattle	Number of warbles	Average
1933	2,230	32,987	16.00†
1934	1 942	5,927	3.05*
1935	1,813	3,690	2.04*
1936	1,821	3,676	2.02*

† Warbles were counted at only one of the three treatments.
* Average figures for the three treatments.

ment of Agriculture, gives the results obtained from the treatments and shows their effectiveness.

Mr. Drummond commented on these figures as follows: It will be noted that in the first year, although only one count was made, the average grubs per head of cattle was sixteen. Had a count been made at the time of each of three treatments the average per head doubtless would have been much higher, for during the three succeeding years the second and third counts revealed larger numbers than the first.

In 1934, a count was made at each treatment and these counts showed an average of 3.05 per head, which is a great reduction from the first year, and was very satisfactory to the island cattle owners. Fewer cattle were treated in 1934, owing to a reduction in the size of herds kept by a number of the farmers.

There was a still further reduction in the number of cattle for the same reason, in 1935. On three counts, that is at each time of washing, the average number of warbles per animal was 2.04. This may be regarded as a satisfactory reduction, and it should be added that had it not been for the purchase of some 20 head of untreated cattle from outside points which showed an average count of about 50 per head, the results would have been even better. The 1936 work showed a still further reduction. The average for three treatments was 2.025 grubs per head. These results would have again been much better had it not been for a large number of untreated animals purchased and brought to the island.

The adjacent village municipality of Bryson, which is joined to Calumet island by a bridge, co-operated with the Calumet island council and materially contributed to the effectiveness of the project by treating all cattle in the village each year.

Résumé

La suppression de l'hypoderme au Canada. A. Gibson et C. R. Twinn, Division de l'Entomologie, Ministère de l'Agriculture, Ottawa, Ont.

Les résultats des enquêtes entreprises sur les oestres *Hypoderma lineatum* DeVillers et *H. bovis* deGeer, et les campagnes de répression organisées et conduites pendant une série d'années par les autorités fédérales, provinciales et municipales, en Colombie-Britannique, dans l'Ontario et le Québec, sont présentés dans cet article. Il est démontré que les lavages au derris et au savon sont utiles pour détruire les larves d'hypodermes dans le dos des bovins infestés, à condition que ces lavages soient appliqués convenablement et de façon systématique.

PHYSIOLOGICAL DISORDERS OF APPLES[1]

H. Hill[2] and M. B. Davis[3]

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The results presented in this paper are taken from observations and investigations conducted during the past five years into certain physiological disorders of apples occurring in the Provinces of Quebec and Ontario. For the purpose of description the disorders studied have been designated under the names of (1) Cork, sometimes further described as internal cork; (2) Corky-core; and (3) Tree Pit or Bitter Pit. Our observations have led us to believe that the first two are but two types of the same disorder influenced in expression by the variety of apple affected. As a general rule the disorder is expressed in the variety Fameuse as internal cork, in the variety McIntosh as corky-core, and in the variety Joyce as a distinct type of internal cork. The varieties Fameuse and McIntosh located in the same orchard and even as grafts on the same tree have evidenced this difference in the expression of the disorder. The variety Northern Spy and various Spy seedlings have been found to be affected with tree or bitter pit. The exact relationship which this disorder has to other forms of cork is not yet clear. In this regard, Carne (2) makes the following statement. "We have found that as cork is formed later and later in the season, it tends to become less and less distinguishable, macroscopically and microscopically, from bitter pit formed on the tree (tree pit). That is to say, in many cases, apples apparently affected with tree pit may from a causal point of view be actually affected with late-formed (and therefore comparatively poorly-developed) cork. For this group which is a homogeneous one symptomatically, but apparently a heterogenous one causally, the term orchard pitting is suggested."

The characteristics of the different types of the disorder are as follows.

Cork, or Internal Cork

This type of the disorder is similar to that described by Mix (7). In the variety Fameuse the disorder takes the form described by Carne et al. (2) under the name of internal cork. In this variety the trouble may appear at the time when the apple is but half grown, in this district the early part of July. At this time the affected fruit does not show external evidence but upon being cut open light brown spots of dead corky-like tissue will be found in the flesh in the region of the core or scattered indiscriminately through the flesh. As the fruit begins to colour, affected apples may be detected on the tree by the blushed or red portion being somewhat darker in colour than normal. Later the affected fruit may become markedly deformed by a large number of discontinuous elevations and depressions, producing a marked knobby appearance (Figures 1 and 2). Fruit so affected drop badly and by harvest time the greater proportion of the crop will be on the ground. No further development of the disorder occurs when affected fruit is placed in storage.

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[1] Contribution No. 465 of the Division of Horticulture, Central Experimental Farm, Ottawa, Ontario. Read before a meeting of the Horticultural Group of the C.S.T.A. at the University of New Brunswick, Fredericton, N.B., July 14–15, 1936.

[2] Assistant in Horticultural Research.

[3] Dominion Horticulturist.

In other varieties such as Joyce the disorder may be considered as a type of internal cork, in which case large necrotic areas occur in the flesh often near the core but also close to the surface. The fruit does not become markedly deformed as in the case of internal cork of the variety Fameuse, but external symptoms are evident in the form of irregular blotchy depressions deep green or mottled green and brown (Figure 3).

Corky-core

In this type of the disorder the affected tissue is generally confined to the core area, either as light brown individual spots of dead corky tissue or as a continuous band or circle around the core resembling a brown flushing. This type of disorder does not appear until the fruit is three-quarters grown or is beginning to mature. As there is no external evidence of the disorder it is only by cutting into the fruit that the trouble may be detected.

Tree or Orchard Pit

This pitting occurs during the late life of the apples on the tree, and according to Carne et al. may be affected with late-formed cork or with tree pit. The first symptom is the appearance of slightly discoloured spots, deeper green on green fruit, darker red in red fruit, somewhat sunken or depressed and generally regular in outline. They are likely to be more numerous toward the calyx end. When an affected apple is cut it shows groups of brown broken down pulp cells just under the skin in the flesh and the affected tissue is generally confined to this area.

As a forerunner to detailed investigations a preliminary survey was made of soil conditions, tree vigour and fertilizer practice in a representative group of 22 orchards in affected areas. A summary of the findings follows. While there is little doubt that these troubles have occurred more on shallow soils and more in dry years than in seasons of ample moisture, or on soils of good depth, there seems sufficient evidence to warrant the assumption that nutrition is one of the chief fundamental causes. The trouble is closely associated with high vigour and is generally found in trees exhibiting high nitrogen symptoms. Low vigour trees in orchards either on shallow or deep soils even in an exceptionally dry season did not exhibit any signs of cork troubles. Many cases were found where the disorder appeared to be associated with manurial practice, generally an excess of pig or hen manure, either alone or with added nitrogen. Where nitrogen feeding had been kept low either by the use of sod alone or by the use of a light mulch without nitrogen, physiological disorders were not found. We were not able to associate the occurrence entirely with soil moisture, although in one area it was suggested that a high water-table early in the spring causing waterlogging might be a factor.

At the Central Experimental Farm, Ottawa, tree pit occurred on Patten Greening under heavy hen manure mulch. This section of the orchard had been heavily mulched for five or six years with the material from the egg laying contest and in addition received 8 to 9 lbs. of a 9-5-7 fertilizer per tree. The same variety growing in the same orchard under clean cultivation and receiving the same fertilizer treatment was free of the trouble. Soil samples were gathered from these two areas and analysed by Hammond (3). In the clean cultivated area the organic matter and

its constituent nitrogen were both rather low. The mulch sample, scraped off the surface to a depth of 4 inches contained a large amount of organic matter and nitrogen as well as mineral constituents. Hammond (3) expressed the view that the nitrogen is probably in excessive amount for the production of good fruit.

Effect of Waterlogging on the Incidence of Cork

Joyce apple trees growing in pots in sand producing healthy fruit for the previous ten years were waterlogged by raising the water-table half way in the pot. This resulted in 100% corky apples, mostly internal cork, and an examination of the roots showed that the entire lower root system had been killed by excessive moisture.

Effect of Time and Quantity of Nitrogen Feeding on the Incidence of Cork

For some years we have been growing Melba apples in pots under varying nitrogen conditions but with moisture kept at an optimum throughout. Cork has been found under these conditions varying from 0 to 100% and appearing to be correlated with prolonged applications of nitrogen. Under low nitrogen conditions or where nitrogen was withheld after early summer the disorder was reduced or eliminated. When nitrogen was fed only until the trees were in full bloom each season, the amount of cork was 6% when fed until the calyx had closed, cork rose to 15%, when fed until September 1st, the amount of cork found was 100%. We were forced to the consideration that these physiological disorders were largely influenced by nutritional treatment irrespective of moisture supply and that they are closely associated with excessive vigour due to over-nitrogen stimulation.

Following such preliminary observations it was decided to make a more detailed study of soil profiles, soil composition and tree root growth in the orchards formerly surveyed. In the Province of Quebec, orchards in the areas of Oka, Hemmingford and Covey Hill were investigated.

OKA AREA

Diseased orchard—Root system

In the first six inches the root system was fairly extensive, fibrous and well branched. In general the roots were healthy in appearance with brown bark. A small proportion of fine rootlets were darkened back from the tips but even in rootlets so affected the core was generally healthy white. The percentage of rootlets considered not to be functioning was estimated at not more than 15%. At this stage it is admitted that the amount of root injury was estimated only upon observation and not on physiological studies of the ability of such roots to perform their normal function. There was a good distribution of the root system from a depth of six inches to four feet (Figure 6). Within this area there was no evidence of difficulty of root penetration, no turning upward of the roots away from the direction of their growth.

The surface soil is a dark medium loam with many small stones, which persists to a depth of a foot. At this depth the soil changed slightly in character containing considerable gravel and weathered rock high in iron and lime. This type of soil persisted to a depth of four feet when a heavy clay zone was found which persisted to the excavated depth of five feet.

In this clay zone tree roots were practically absent, only one or two roots occurring on the border line of the clay horizon. Small quantities of shell were found in the 3 to 4 feet depth. An observation glass was placed on the face of the trench in order to observe the extent of root growth (Figure 7). After a period of two months the amount of root growth was observed, very satisfactory growth having occurred, white and healthy in appearance.

Suit (9), and Hunter (Figures 8 and 9) of our own division examined the roots of some diseased trees from this area and reported that there appeared to be a plugging of the feeding roots with some undetermined material, whereas in disease free trees from Macdonald College or from healthy trees in the same area this did not appear to be the case.

Healthy Area-soil Profile

In the first two feet the root system was fairly extensive, fibrous in nature but not more extensive or branched than in the diseased area. The majority of the roots appeared healthy although there was some browning and blackening of the finer rootlets. There was by observation apparently no more or less root injury than was found in the diseased area. This root system had not the depth of distribution found in the diseased tree as it tended to become very sparse beyond the two-foot level.

The surface soil was a black medium loam, 1 foot in depth, then becoming lighter. This type of soil continued to the two-foot level with very little gravel or larger stones. At the two-foot level, the soil contained considerable portion of clay but there was no definite clay zone until a depth of two and one-half feet. From three to four feet there was a zone of pure clay into which the tree roots did not penetrate. Trees in this area had a shallower root growing area than trees in the diseased area.

We were not able to establish any correlation between the amount of root injury and the occurrence of these disorders. A certain amount of killing of fine rootlets was found both in healthy and diseased trees and it is suggested that the amount of injury so found takes place as a normal function (5). The diseased trees were found to be growing on a soil of good depth, fairly well drained, in a good physical condition offering no obstacle to root growth. In comparison the soil profile in the unaffected area showed that the root system did not have an equal depth of distribution due to a clay zone which prevented root penetration.

Chemical Data

One of the greatest differences between these soils was the available phosphorus content and the P/K ratio, especially in all horizons below the surface soil, where tree roots were freely growing, being much higher in the diseased area. Blenkinsop (1) states severe instances of potash deficiency are often associated with a high potash level masked as it were by an excessively high phosphate level. A rather surprising fact is the high nitrogen content from the unaffected area as compared with that from the diseased. Easily soluble calcium was lower in the soil from the healthy area, while soil reaction was slightly acid in the surface soil and slightly alkaline beyond a two-foot depth compared with an alkaline reaction at all depths in the diseased area.

FIGURE 1. Exterior of Fameuse apple affected with internal cork.

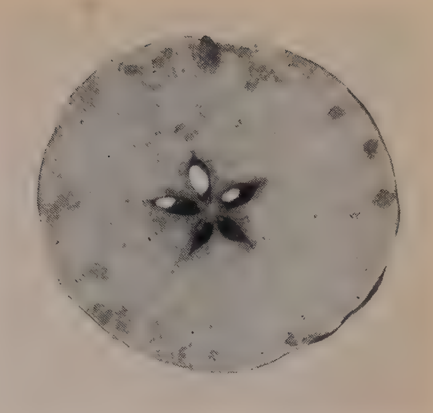

FIGURE 2. Interior of Fameuse apple affected with internal cork.

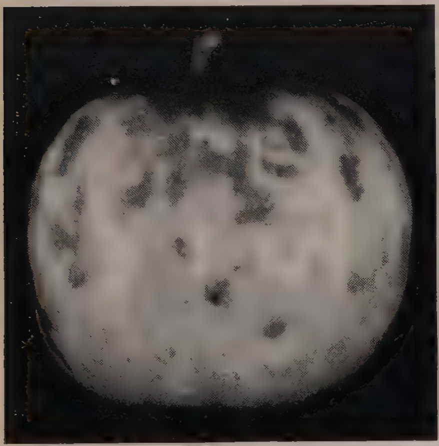

FIGURE 3. Internal cork on Joyce variety

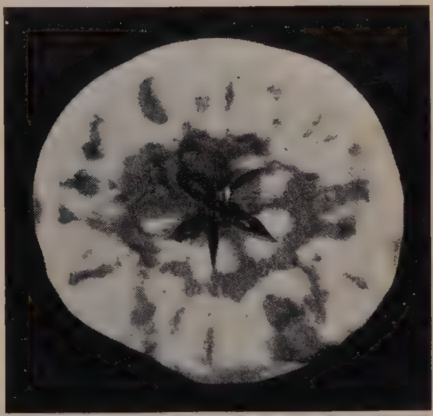

FIGURE 4. Joyce apple affected with type of internal cork.

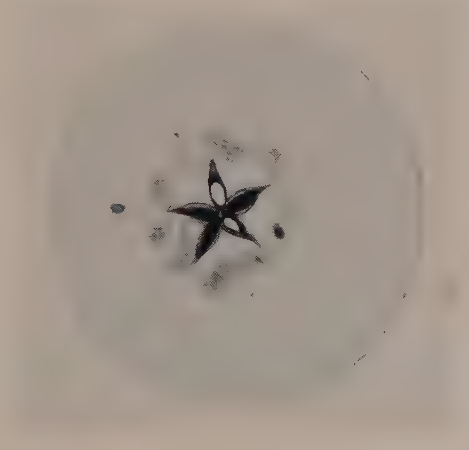

FIGURE 5. Corky-core in the variety McIntosh.

FIGURE 6. Soil profile at Oka—Diseased area. Note cessation of root growth at the four-foot level where clay horizon commences.

FIGURE 7. Root growth on soil profile diseased area—Oka.

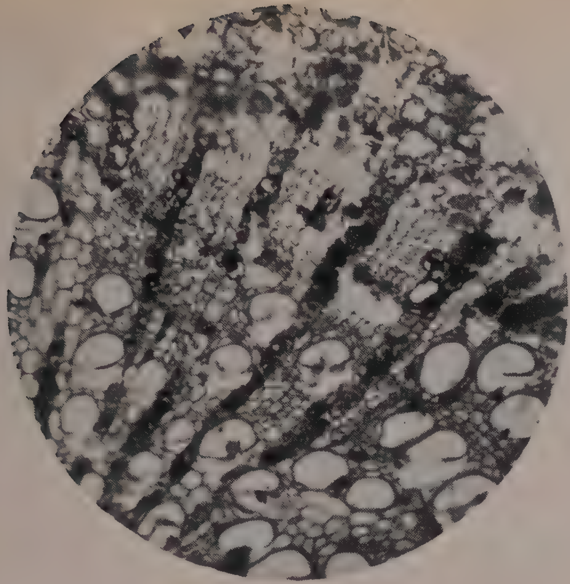

FIGURE 8. Microscopic section of root from diseased area—Oka. Note plugging of cells.

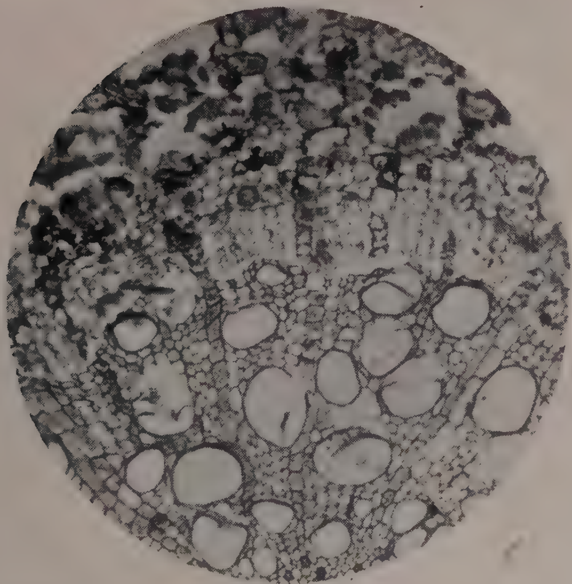

FIGURE 9. Microscopic section of root from healthy area Oka—cells practically free from plugging.

FIGURE 11. Interior of apple shown in Fig. 10.

FIGURE 10. Tree pit in Spy Seedling.

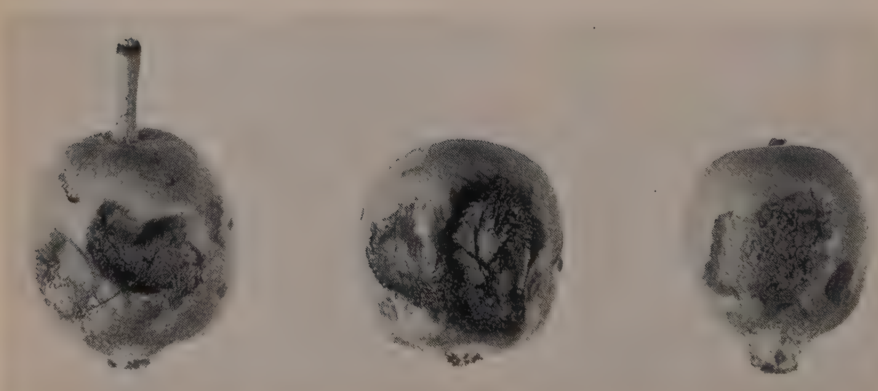

FIGURE 12. Apples affected with drought spot.

TABLE 1.

DISEASED AREA

Depth in inches	pH	Loss on ignition	Per cent nitrogen on moisture free basis	Readily available mgms. of p in 100 gms. soil. Lohse & Rhunke (6)	Readily available mgms. K_2O in 100 gms. soil. Volk & Truog (10)
6– 6	7.5	4.08	.150	23.4	19.5
6–12	7.4	3.37	.060	26.5	9.5
12–24	7.6	3.47	.028	50.8	6.5
24–36		3.14	.021	29.0	5.5
36–48		7.63	.016	29.0	4.5
HEALTHY AREA					
0– 6	6.7	10.11	.393	12.4	21.0
6–12	6.75	7.78	.298	7.9	10.0
12–24	7.0	5.60	.201	6.8	9.5
24–36	7.30	3.97	.126	21.6	8.0

HEMMINGFORD AREA

In this area soil conditions and root growth were found to be fairly uniform in the various orchards investigated, so that it will be sufficient to give a detailed profile description found in one orchard. It may be said that in this area physiological disorders were largely confined to orchards or individual trees heavily manured. In the orchard cited a large amount of cork was present over the entire orchard. This orchard had been mulched very heavily for seven years with hen manure and straw in sufficient quantities to kill all grass growth around the trees. Trees made very vigorous growth and were excessively large for their age with foliage a dark green colour. The roots were found to occur very close to the surface immediately under the mulch. In general, roots were found to be bright and healthy, light brown in colour, although there was a small percentage of root blackening and injury. An examination of the root system of trees known to be unaffected revealed a like amount of root injury so that we were unable to establish any correlation between the occurrence of these troubles and the amount of root injury present. Anatomical examination of roots from diseased trees did not show any evidence of "plugging" as was found in the Oka area (Figure 8). In the surface soil the amount of roots present was moderate to plentiful with fibrous roots well branched. The surface soil is a light sandy loam 9 inches in depth. At this depth the soil commences to get very compact and hard in nature with a considerable proportion of clay. Below a depth of one foot, the fibrous roots became scarce and practically ceased at a depth of 2½ feet. At a depth of 1½ feet and continuing downward a considerable proportion of slaty gravel occurred and the soil was very hard and compact. This is a very shallow soil with poor drainage qualities and would probably have a high water-table in the spring and a deficiency of moisture in midsummer, due to the compact subsoil. On account of the almost hardpan-like nature of the subsoil the trees are shallow rooted. In this area it is considered

that high level fertilizing is dangerous especially with nitrogenous materials, since the nutrient balance might be easily upset on account of the shallow feeding habits of the trees due to compacted subsoils. For the same reason limited root development will not permit the carrying of an extremely vigorous top bringing about conditions of moisture deficiency.

Chemical data

TABLE 2.

Depth in inches.	pH	Loss on ignition	Per cent nitrogen on air dry basis	Readily available mgms. P in 100 gms. soil. Lohse and Rhunke (6)	Readily available mgms. K_2O in 100 gms. soil. Volk and Truog (10)
Mulch material		41.25	1.720	35.0	49.6
0–9	6.6	7.92	.281	13.1	19.0
9–21	7.3	2.85	.059	18.5	5.0
21–40	7.7	11.50	.020	16.0	7.5

The surface soil was slightly acid in reaction but the lower horizons were definitely alkaline with a high calcium content. Organic matter and total nitrogen were high as might be expected from the past fertilizer treatment. In the lower horizons the readily available potash was low expecially in ratio to the readily available phosphorus.

COVEY HILL

In this area fertilizers have been employed in a much more restricted sense than in the Hemmingford area. A complete fertilizer was more generally employed and not in excessive amounts. Hen and pig manure were not generally made use of as orchard fertilizers as in the Hemmingford area. Physiological disorders have been largely confined to individual trees which have received larger amounts of nutrients due to their position, such as trees situated in a henyard, in a vegetable garden heavily manured or close to a barn where manure leaching would affect the trees.

Typical Orchard Soil and Root Growth

In the orchard cited a heavy mulch has been applied in addition to the grass cut and left in the orchard but no fertilizer has been used. Trees are free of any signs of physiological disorder with the exception of one in the garden which has been heavily manured each year. The trees are healthy and vigorous with large leaves of a good green colour. The surface soil was found to be a good dark loam about 8 inches in depth getting lighter in colour with a proportion of gravel in the subsoil. This type of soil persisted to a depth of 20 inches when it changed slightly to contain a small proportion of clay to a depth of four feet. In this area there undoubtedly exists a much better physical condition of the soil than in the Hemmingford area. The soil is of good depth with adequate drainage but with good water holding capacity. The root system was fairly extensive with fibrous roots well branched. Slight root injury was present to about the same extent as found in other districts.

Chemical Data

TABLE 3.

Depth	Loss on ignition	pH	Readily available mgms. of P in 100 gms. soil	Readily available mgms. of K_2O in 100 gms. soil	Per cent nitrogen on air dry basis
0–8	11.32	6.5	1.9	13.0	.454
8–20	4.17	6.5	3.8	5.5	.146
21–33	4.43	6.7	11.7	8.5	.117

Although nitrogen is at a high level and organic matter plentiful, it differs materially in the phosphorus content from the Hemmingford soils, being much lower in the present instance, almost on the deficient side. The P/K ratio would appear to be at a better level. It will be noticed that the soil reaction is slightly acid compared with definite alkalinity in the Hemmingford area.

In one orchard in this area soil moisture was definitely deficient being as low as 3.4% while other orchard soils in the same district had a moisture content of 18%. The soil was very gravelly, open in texture with a very low water-holding capacity. The tree roots commenced immediately under the sod tending to come to the surface seeking moisture, a partial indication that the water-table was very low. Despite the fact that moisture was a decidedly limiting factor in this orchard, physiological disorders had not occurred. The trees are in sod, no mulch or fertilizer ever having been applied. The trees are making very little growth and this is definitely a low-nitrogen orchard. It is felt that had a high state of soil fertility existed, physiological disorders would have been serious under these conditions.

BRIGHTON, ONTARIO

Every tree in a block of young McIntosh is severely affected with corky core. These trees have been manured heavily each year. The soil is alkaline in reaction (pH 8.0) and gives a strong reaction for carbonates, and calcium and iron are high. The surface soil is a light sandy loam about 12 inches in depth. It then changes to a greyish sand containing a small amount of clay. This type of soil extended to a depth of over 4 feet. Tree roots were sparse though healthy in appearance. The profile was made early in the spring and at this time there was no sign of a subsoil difficult to penetrate, but on account of the nature of such soil it is considered a very compact hard type of subsoil might result later in the summer.

CHEMICAL TREE INJECTIONS

Limbs of Duchess of Oldenburg trees were injected with salts in powder form. Four holes 6/16 of an inch in diameter, about 2 inches deep, were bored spirally around the circumference of the limb,

Salt used	Amount, grams	Per cent water core
Potassium sulphate	10	26
Ammonium nitrate	18	46
Complete fertilizer	17	4
Calcium acetate	24	24
Superphosphate	18	18
Check	—	22

each hole was packed with the specific salt the opening then being covered with arcomastic.

The complete fertilizer injection exercised considerable effect in controlling water-core, while the nitrogen injection increased the severity.

At Brighton, Ontario, limbs of trees known to be affected with corky-core were injected. All treatments were conducted in duplicate.

Salt used	Amount, grams	Per cent corky core
Potassium chloride	14	100
Check	—	94
Sodium hydrogen phosphate	16	92
Ammonium nitrate	15	97
Sugar	17	100
Zinc sulphate	1	80
Copper sulphate	1	97
Boric acid	1	60
Manganous sulphate	1	100

Boron exercised a significant effect in the control of this disorder even though used in such small amount, while there was an indication that zinc sulphate might also exercise a controlling influence.

Further Evidence of the Effect of Boron in Controlling These Disorders

Trees in pots known to be affected with internal cork brought about by waterlogging or subjecting to drought conditions were fed a fertilizer solution containing nitrogen at a fairly high level. Half of the trees received boron at the rate of 1 part per million in the nutrient solution. Trees not receiving this element continued to be affected with cork while those receiving it recovered entirely from the disorder.

During the latter part of June of this year our attention was drawn to a disorder occurring in several orchards in the Brighton area. Affected fruits were characterized by superficial or sunken irregular dead brown spots or patches in the skin of the fruit, more often found at the calyx end, but not entirely confined to this area. In severe cases the fruit was somewhat deformed and cracks appeared in the affected portion. The disorder is considered to be similar to that described by other workers under the name of drought spot. Examination showed that the soil, especially the subsoil was alkaline in reaction, high in carbonates. In one corner of the orchard the soil was different in character being slightly acid in reaction, low in carbonates. In this area the trees were almost free from the disorder. The trouble was also found on the block of young McIntosh previously described as being affected with corky-core. Early this spring 8–10 grams of boric acid were injected into the trunks of several trees. Trees so injected are apparently free from drought spot while surrounding trees are badly affected.

SUMMARY

No correlation was established between the amount of root injury and the occurrence of these troubles. A certain amount of killing of fine rootlets was observed both in healthy and diseased trees but not in significant amount or difference. In the Oka area there was a certain amount of plugging of medullary tissue in the case of roots from diseased trees but this did not hold for any other locality. Experimentally internal cork was

produced by waterlogging or subjecting to drought trees which were growing in pots and which had produced healthy fruit for the previous ten years. With pot-grown trees there was a marked correlation between the occurrence of the disorders and prolonged heavy applications of nitrogen, irrespective of any other factors. In the Oka area the occurrence of these disorders was not correlated with the physical condition of the soil. While adverse soil physical conditions were found to exist in practically all orchards examined in the Hemmingford district, physiological troubles were generally confined to areas heavily manured or fertilized. Even in this district where trees were shallow-rooted due to compacted subsoils, where the water-table was high in the spring and moisture deficient in the summer, the level of nutrition was the deciding factor as to whether these disorders occurred. In one orchard in the Covey Hill section, where moisture was decidedly a deficient factor but the nutrient level low, no physiological disorders occurred.

One of the chief soil characteristics in all affected areas was the alkaline reaction and high lime content in the form of carbonate. Nitrogen content was high and the easily available P/K ratio was high compared with non-diseased orchards.

In correspondence with Dr. R. R. McKibbin, Macdonald College, the statement is made that the work of the Quebec Soil Survey confirms our findings as to the correlation of high carbonate-lime content of soils with corky core in apples. The opinion is expressed that "the high pH values and high calcium content brought about by accumulation of fairly soluble lime carbonates, in subsoil horizons, is the chief contributing soil factor in causing this physiological disorder." The effect of this factor may be direct or indirect.

"Apparently it: (1) Increases nitrification and therefore the availability of nitrogen to the tree which may thus get an excess of nitrogen, (2) Decreases boron availability to the tree, (3) Interferes with free passage of soil water up or down (8)."

Applications of boron either fed as nutrient solution to trees in pots or injected into trees in the solid form in the orchard gave evidence that this element exercised a control of the disorders internal cork, corky core and drought spot. In this regard it has been pointed out that at high pH's due to over-liming or a natural high lime or magnesia content of the soil the boron may be relatively unavailable (4).

The conditions we have found associated with these disorders in apples are as follows:

(1) High carbonate lime soils.

(2) High percentage of nitrogen and organic matter, especially in association with shallow-rooted trees brought about by compact subsoils.

(3) Soil moisture excesses and deficiencies in association with high percentage of nitrogen and organic matter.

(4) Low available potash and a high phosphorus-potassium ratio, especially in the lower soil horizons.

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Résumé

Affections physiologiques des pommes. H. Hill et M. B. Davis, Ferme expérimentale centrale, Ottawa, Ont.

On a réussi à produire expérimentalement le liège interne en imprégnant la terre d'eau ou en privant d'eau les arbres qui étaient cultivés en pots et qui avaient produit des fruits sains pendant les dix années précédentes. Dans les arbres cultivés en pots, il y avait une corélation marquée entre la présence du liège interne et des applications prolongées et abondantes d'azote. Une étude des sols d'un groupe de vergers affectés, a révélé que les désordres ne sont pas limités aux arbres poussant sur les sols en pauvre état physique ni même sur le sols peu profonds, à sous-sol compact; le niveau de nutrition paraît être le facteur principal. Les conditions qui s'associent généralement à ces désordres sont les suivantes: 1. Sols calcaires riches en carbonates; 2. Gros pourcentage d'azote et de matière organique, surtout chez les arbres à racines peu profondes, à cause du sous-sol compact; 3. Excès et insuffisance d'humidité, joint à un gros pourcentage d'azote et de matière organique; 4. Peu de potasse assimilable et forte proportion de phosphore et de potasse dans les horizons inférieurs du sol. Des applications de bore, données sous forme de solution untritive aux arbres en pots, ou injectées dans les arbres sous forme solide, dans le verger, ont démontré que cet élément s'opposes à l'apparition du liège interne, du coeur liégeux et de la tache de sécheresse.

TURNIP BROWN HEART[1]

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INTRODUCTION

Turnip brown heart has been under investigation in Canada since 1928, a year when this disease proved to be the direct cause of very considerable losses to farmers in Eastern Canada. The average yearly turnip production in Canada is estimated at approximately 40,538,000 bushels (1). Of the ten million bushels grown in the Maritime Provinces alone, one million bushels are exported to the United States annually. From such facts it is clear that any condition adversely affecting this important crop reacts upon our farming communities and may represent considerable financial loss to many individual farmers. The significance of this statement will appear when it is known that vast quantities of turnips are rejected yearly because of brown heart, resulting in a direct cash loss of $50,000 in one single year, an estimate based upon rejections at shipping points (2).

Scientific and farming literature have had very little to say about brown heart. In 1910 it was first mentioned in Canada by the Dominion Botanist (3) when speaking before the Select Standing Committee on Agriculture and Colonization. Later, Woods (4) of Maine reported upon what unquestionably was a similar condition which he called "Black heart." Subsequently, in the year 1928, because of the serious prevalence of brown heart, the Dominion Botanist, through the Charlottetown Laboratory, organized an intensive research program for the purpose of studying the problem. In 1933 the Federal authorities appointed a committee to study turnip diseases in Eastern Canada. This group comprises a central body under the chairmanship of Dr. E. S. Archibald, Director of the Dominion Experimental Farms Branch. Co-operating with the organization is a Maritime Committee under the chairmanship of Mr. C. F. Bailey, Superintendent of the Experimental Station at Fredericton, New Brunswick, the other members being chosen from the Forage, Botany and Illustration Divisions represented in the Maritime Provinces. The success of this effort has been due largely to the extensive tests conducted on the Experimental Farms, Illustration Stations, and Plant Pathological Laboratories operated in Nova Scotia, New Brunswick and Prince Edward Island. This research program has brought out much valuable knowledge concerning the cause and prevention of turnip brown heart.

The occurrence of brown heart has been reported in Denmark, Finland (5), Norway, the British Isles (6), the United States (Massachusetts and Maine), Canada (British Columbia, Ontario, Quebec, Nova Scotia, New Brunswick, Prince Edward Island), New Zealand and Germany. No doubt a complete survey would reveal its presence wherever turnips are grown.

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SYMPTOMS OF BROWN HEART

Brown heart occurs most commonly in turnips of greater diameter than two inches, although occasionally it may be seen in very small roots. Its development is most definite towards the latter half of the growing season but has been observed in late July and early August while the roots were still small. It is not possible to tell brown heart by an examination of the growing parts above the surface of the ground. The only sure method, therefore, of detecting its presence is by cutting into the turnip, although O'Brien and Dennis (6) report clear cut evidence indicating that the fibrous roots of affected plants are more poorly developed than those of healthy ones. The opinion has been expressed that the frequent cracking of the tissues in the region of the "neck" is an indication of brown heart.

Brown heart is illustrated in Figure 1. In the natural state typical symptoms would be recognized as a clearly defined brownish and mottled area appearing in sharp contrast with the lighter coloured unaffected tissue. When freshly cut this surface is glassy and the affected area appears definitely water-soaked, the condition responsible for such names as "water-core" and "water heart", used appropriately as alternative terms for this disorder. In cross-section, brown heart may be further detected by the very frequent occurrence of concentric light and dark markings. Upon close inspection these rings are seen to conform with what are actually the isolated groups of vessels in the radial lines of the turnip tissue and arranged in a circular fashion. When exposed to the air for a short time the darker portions become sunken, while the light, or normal, tissue retains its original appearance. Because of the striking similarity between the isolated groups of vessels and a definite brown heart condition there exists some confusion as to what actually constitutes the minimum symptoms of brown heart. This important point is illustrated by Figures 1a, 1b and 1c, representing no brown heart, slight, and general types respectively. The tissue subject to brown heart is restricted to the central part of the turnip comprising from 70% to 80% of the cut surface, the remaining 20 to 30% constituting the outer area not subject to this condition. By examining the illustrations it will be seen that there is a tendency for the sound and affected areas to alternate with one another.

Brown heart may involve 75% of the turnip root or be restr'cted to small isolated areas. Intermediate stages are likewise noted which seem to suggest that the breakdown is a gradual process terminated by the pulling of the turnip. In cases of severe brown heart the tissue may develop cavities due to the breakdown of the cells (Figure 3), and at this stage rots may be induced by the action of the rot-producing organisms which occur so abundantly in nature.

In addition to suffering a loss of dry matter and a reduction in sugar content, affected turnips do not store satisfactorily, inasmuch as they lose weight through loss of moisture. For this reason they become spongy, a condition rendering them useless for human consumption. Brown heart does not increase in storage but the symptoms may be lessened on account of the drying out process.

THE CAUSE AND CONTROL OF BROWN HEART

Warrington (7) in 1923 and Sommer and Lipman (8) in 1926 and others have demonstrated that a number of plants benefit by minute amounts

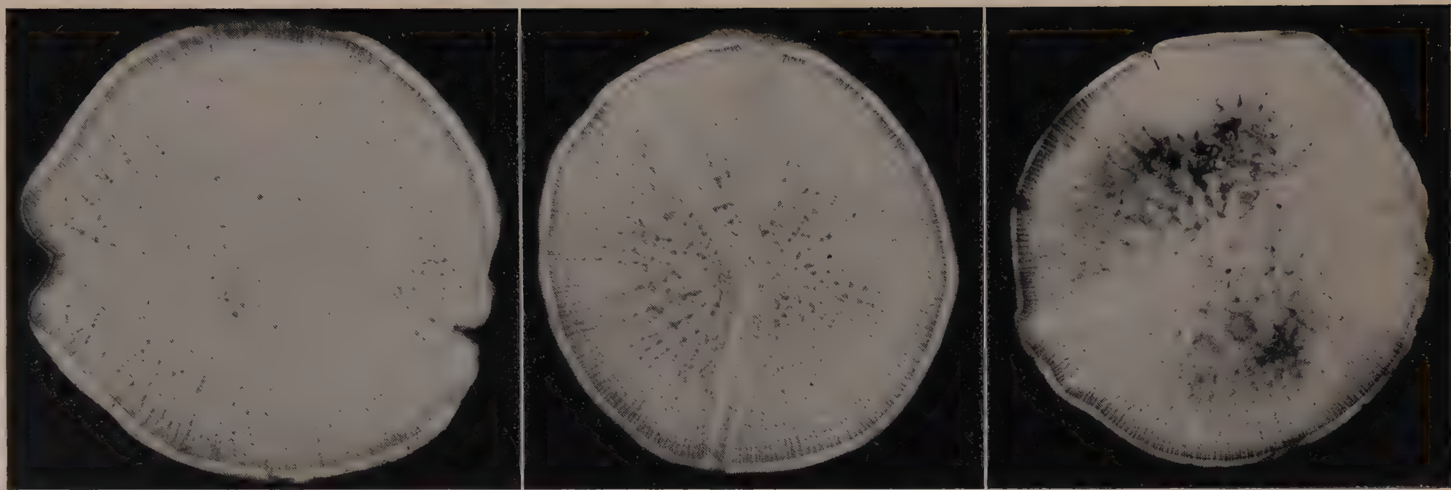

Figure 1

a. Healthy turnip. *b.* Brown heart of the slight type. *c.* Typical or general brown heart.

FIGURE 2. A case of severe brown heart in which the destruction of the cells produced cavities.

FIGURE 3. Longitudinal section of a turnip illustrating the manner in which brown heart develops mainly in the lower half.

FIGURE 4. Turnips from adjacent rows in a commercial test. The turnips on the right were treated with borax at the rate of 10 pounds per acre, those on the left were untreated.

of the element boron. Inspired by these findings MacLeod and Howatt (9, 10) conducted researches in 1933 which demonstrated that the turnip also requires boron for its normal development and discovered that a lack of this element in a soil may cause brown heart. O'Brien and Dennis (6). Grant and Hill (11), and Jamalainen (5) reported similar findings in 1935, Critical laboratory trials showed that borax is the most satisfactory source of boron for brown heart control. In order to test on a practical scale the value of borax as a corrective for brown heart, a series of trials was conducted at 3 Experimental Stations and 22 Illustration Stations in the Maritime Provinces. In these trials the borax was tested in combination with fertilizer and manure. Although significant results were obtained from the trials conducted in 1933 and 1934 data from these are omitted for the sake of brevity.

The results obtained in 1935, however, are presented in Table 1.

TABLE 1

Treatment	Rate per acre	Percentage brown heart
Fertilizer (2–12–6) + borax	1000 lbs. + 15 lbs.	32.59
Manure + borax	20 tons + 15 lbs.	42.79
Manure	20 tons	55.20
Fertilizer (2–12–6)	1000 lbs.	67.16
Manure + fertilizer (2–12–6)	20 tons + 500 lbs.	67.45

The results summarized in this table show that borax at the rate of 15 pounds per acre in combination with manure or chemical fertilizer effected a high degree of control of brown heart under the conditions of these trials. Borax in combination with fertilizer was superior to borax combined with manure and manure alone. Manure was slightly more effective than fertilizer. It would appear from these results that manure contains traces of certain elements, probably boron compounds not included in artificial fertilizer, which serve as a corrective for brown heart. From 20 to 40 tons of manure are ordinarily required, however, for adequate control of the disease.

The results of trials conducted under commercial conditions in the Maritime Provinces, Quebec, Ontario, and British Columbia also showed that borax at rates ranging from 15 to 20 pounds per acre effected a satisfactory control of brown heart on a variety of soils (Figure 4).

Practical field trials showed that heavy liming of the soil increases the susceptibility of the turnip to brown heart, and also that the borax treatment is less effective on soils that are naturally alkaline or have received heavy applications of lime, mussel mud, and other substances capable of creating alkaline conditions. Additional tests showed that there is a tendency for less brown heart on the heavier and waterlogged soils

Experiments on the after effects of boron on different crops showed that at rates ranging from 15 to 20 pounds per acre the chemical is not injurious to potatoes, wheat, oats, barley and timothy in rotations following turnips.

A yellowing of the young leaves of turnips and other crops sometimes results from the use of borax, but this condition disappears in the course of a week or two without causing any undue later effects to the crop so affected. Turnips grown on boron-deficient soil occasionally develop a reddening of the leaf margins which in severe cases may extend and involve the entire leaf blade. Leaves so affected usually drop off the plant. Turnips supplied with boron are superior in quality and flavour to those grown on soils depleted of this essential element.

While boron is available commercially in several forms the most convenient and inexpensive source is borax. The finely powdered product is recommended in preference to the crystalline form which sometimes contains large lumps that may concentrate the chemical sufficiently to cause a decrease in yield.

From 15 to 20 pounds of borax per acre has proven most satisfactory for the control of brown heart and causes no injury to the crop or significant effect upon the yield. Since large amounts of borax are toxic to many species of plants, applications exceeding 20 pounds per acre should not be attempted.

METHOD OF APPLICATION

While favourable results have been obtained by applying the chemical broadcast the direct-in-the-drill method appears to be most satisfactory. The chemical may also be applied with satisfactory results at the sides of the row. The borax can be distributed successfully in combination with the fertilizer and applied by means of the ordinary fertilizer distributing machinery. Uniform mixing of the chemical with the fertilizer is extremely important. This can be simplified by first mixing the borax with 5 to 10 times its own weight of fine sieved earth, sand, gypsum or other suitable spreading material and then thoroughly incorporating this mixture with the bulk of the fertilizer. Mixing the borax by means of a suitable mechanical mixer such as is used by fertilizer dealers is recommended in preference to mixing by hand. If the farmer does not use fertilizer the borax should be mixed with sufficient suitable spreading material until the bulk required for easy handling is obtained. A convenient amount is 85 pounds of spreader to 15 pounds of borax. Satisfactory control of brown heart has also been obtained by spraying the required amount of borax on the soil or foliage of the turnip. Applications should not be made later than August 1. While this method facilitates uniform distribution it involves additional labour and for that reason is only recommended for small lots of turnips. When the borax is used in dry form it should be applied a week previous to sowing the seed in order to prevent retarding germination.

The importance of uniformly distributing the boarx cannot be over emphasized. Unsatisfactory distribution may result in parts of the field not receiving enough of the chemical for satisfactory control and others an excessive quantity harmful to the crop.

The general inclusion of borax in commercial fertilizer for the turnip crop is not recommended at present because there are still many cases where additional boron is not required. Furthermore there is such a wide variation in the amounts of fertilizer used that it would be difficult for the farmer to correctly compute the amount that would be adequate for brown heart control and not injurious to the turnip crop.

While borax is beneficial to certain other crops, mixtures containing this chemical (including fertilizer) should not be used for crops other than the turnip until a soil specialist or plant pathologist has been consulted.

Growers of turnips where crops suffer from brown heart are ensured of a high measure of control of this trouble by using borax on the lines indicated in this article.

SUMMARY

1. Vast quantities of turnips are rejected yearly because of brown heart, a disease which has been under investigation since 1928.

2. Brown heart is not recognized by external symptoms. It may occur in very small turnips but is found most commonly in roots greater than two inches in diameter. When cut through crosswise typically affected turnips exhibit a clearly defined brownish, mottled, water-soaked and glassy area. Spots, or intermediate stages suggest a gradual tissue breakdown. In advanced stages cavities frequently form, a condition occasionally associated with rot.

3. Tests conducted over a period of three years in the Maritime Provinces demonstrated that turnips require boron for normal development and further that the addition of this element to the land is a safeguard against brown heart. Finely powdered borax has been the most satisfactory source of boron for this purpose, 15 to 20 pounds per acre giving highly satisfactory control without causing injury to ordinary crops in subsequent rotations.

4. Heavy liming of the soil predisposes the turnip to brown heart, while naturally alkaline soils render borax less effective.

5. Proven methods of applying borax are as follows:—

(1) In the drill; (2) at the sides of the drills; (3) broadcast; (4) combined with the fertilizer and dispersed by means of ordinary machine spreaders.

6. The general inclusion of borax with commercial turnip fertilizer is not recommended at present.

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Résumé

Coeur brun des navets. R. R. Hurst, et D. J. MacLeod, Laboratoire fédéral de pathologie végétale, Charlottetown, I.P.-E., et Fredericton, N.-B., respectivement.

Il se perd tous les ans de grandes quantités de navets à cause du cœur brun, une maladie qui est à l'étude depuis 1928. Le cœur brun ne se manifeste pas par des symptômes extérieurs, il peut se rencontrer dans les très petits navets, mais on le trouve le plus souvent dans les racines dont le diamètre dépasse deux pouces. Une coupe à travers un navet affecté d'une façon typique révèle une étendue vitreuse, imprégnée d'eau, marbrée et brunâtre, bien définie. Une décomposition graduelle du tissu est indiquée par des taches, qui sont les phases intermédiaires. Dans les phases avancées, il se produit souvent des cavités, un état qui s'associe parfois à la pourriture. Des essais conduits pendant une période de trois ans dans les Provinces Maritimes ont démontré que les navets exigent du bore pour un développement normal. Ils ont démontré également que l'addition de cet élément à la terre est une garantie contre le cœur brun. Le borax en poudre fine est la meilleure substance pour fournir le bore; une quantité de 15 à 20 livres par acre donne un contrôle très satisfaisant, sans que la récolte en souffre dans les assolements suivants. Un chaulage exagéré du sol prédispose les navets au cœur brun, tandis que les sols naturellement alcalins rendent le borax moins efficace.

Le borax s'applique de la façon suivante, dont l'utilité a été démontrée:—

(1) Dans la ligne des semailles; (2) sur le côté des lignes; (3) à la volée; (4) combiné avec l'engrais et épandu au moyen d'un épandeur ordinaire.

On ne recommande pas actuellement de mélanger le borax avec l'engrais commercial employé pour les navets.

PRELIMINARY INVESTIGATIONS ON THE EFFECT OF EXCESSIVE SOIL SALINITY ON THE INCIDENCE OF CEREAL ROOT ROTS[1]

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INTRODUCTION

During 1934 and 1935 unusually severe attacks of root rot, caused by species of *Helminthosporium* and *Fusarium*, were observed in definite areas in a number of fields of cereals, particularly wheat, in Manitoba. In such areas the plants were dwarfed, and, in addition to the prominent lesions on the plant bases, normal tillering was absent. The basal leaves wilted early and turned reddish-brown in colour. A conspicuous feature in the diseased areas was the thinness of the stand.

Owing to the fact that the severe type of root rot was confined to restricted parts of the fields, and as take-all (*Ophiobolus graminis* Sacc.) was absent, some soil derangement was suspected. Upon examination of the upper part of the soil profile, a layer of white crystalline material was found just below the soil surface. Usually this deposit was most abundant in soil of the lower-lying portions of the fields. Soils collected from such areas were analysed, and in every instance where a very severe attack by root-rotting fungi had occurred a high concentration of soluble salts was found. Analyses of two soil types are given in Table 1.[3]

TABLE 1.—ANALYSES OF TWO MANITOBA SOIL TYPES. SAMPLES COLLECTED FROM WHEAT FIELDS SEVERELY DAMAGED BY ROOT ROT

Soil type	Condition of crop	Cations			Anions			Total salts	
		Ca	Mg	Alkalies (Na, etc.)	SO_4	Cl	HCO_3	Parts per million	Per cent
Red River Clay	Healthy	249	136	96	445	22	446	1.394	0.14
	Diseased plants stunted, or dead	3,054	1,445	746	13.142	55	384	18,836	1.88
Northwestern Drift	Diseased plants stunted, many dead	2,231	886	2,518	13,802	82	246	19,765	1.97
	Diseased plants badly stunted	1,509	1,263	1,184	9,962	636	330	14,889	1.49

No soluble carbonate present as Na_2CO_3.

Salinity in Manitoba soils was found to vary considerably in different areas. In the Red River Valley, with the exception of the western portion, the soils were not found saline. In Western Manitoba, saline soils appeared

[1] Contribution No. 462 from the Division of Botany, Experimental Farms Branch, Department of Agriculture, Ottawa, Canada.
[2] Assistant Plant Pathologist.
[3] Soil analyses and data on the distribution of saline soils in Manitoba were secured through the courtesy of Prof. J. H. Ellis, Dept. of Agronomy, University of Manitoba, Winnipeg.

to be quite common, but these were generally found in parts of fields to which free water had carried soluble salts from surrounding higher land. A large proportion of the Central Plains of North America has also been shown by other investigators, such as Dorsey (2), to be highly salinized. As these regions are largely devoted to the growing of cereals, the relation between soil salinity and the incidence of root rot in these crops was considered worthy of further study.

A review of the available literature showed that, while a great deal of work had been done on the direct effect of soil "alkali" on plant growth, not much information could be obtained concerning the effect of high concentrations of soluble salts in the soil on the development of plant disease caused by fungus parasites. Bolley (1), in 1913, reported that root-rotting fungi caused "death of wheat in alkaline areas otherwise not sufficiently alkaline to injure the crop". He also made the following statements: "We find that a slight excess of alkalinity plus root fungi is very destructive to wheat, but when such land is purified, the wheat thrives well" and, "Studies upon the crop as grown in alkaline areas have convinced us that the chief damage occasioned by ordinary alkaline lands is largely heightened or increased by the presence of the root diseases of cereal crops. In both flax and wheat a number of definite experiments show that the addition of alkalines to already alkaline areas results in the very much heightened condition of the development of the diseases. In the case of wilt resistant flax, flax which is thoroughly resistant to wilt becomes non-resistant when the ground is made slightly more alkaline than that upon which the resistant seed was originally developed by selection and cropping against a thoroughly wilt infected soil. On examination of alkaline wheat areas, our experiments show that what is often considered to be fairly alkaline land will produce good growths of wheat if the ground is sterilized or otherwise purified. It is found by experiment that a number of the root fungi which are destructive to wheat and flax develop very much more rapidly in the presence of alkali than in less alkaline areas. The conclusion drawn from this line of experiments is that very many of the so-called alkaline areas which are now supposed to be too alkaline to produce wheat would be found to grow the crop in good shape if the root-rot diseases were eliminated by proper rotation, proper tillage and seed purification". Humphrey (4) showed that, in Minnesota, the Dakotas, and Montana, wherever wheat is grown in the so-called "alkaline spots" within fields, the plants are usually severely attacked by root-rotting fungi. He also pointed out that the diseased plants showed characteristic symptoms of phosphate deficiency. Evans (3) reported that root rots of wheat were very severe in alkaline soils in North Dakota. Massey (5) found that, in the Sudan, root rot in cotton plants was associated with alkali in the soil.

EXPERIMENTAL RESULTS

In any study of soil and its microbiology a large number of complementary or opposing environmental factors must be considered. This complexity of factors makes experimentation difficult, and at the same time may lead to an incorrect interpretation of experimental data. Experiments in which only one or a few factors are controlled cannot be expected to

yield data that are a wholly reliable index of microbiological activities in the soil, for under natural conditions certain individual factors, or combinations of these, constantly vary in their bearing on other individual factors or combinations. Nevertheless, this type of experimentation helps toward an understanding of some of the reactions which take place in a complex medium such as field soil. In the present experiments at least two factors were controlled simultaneously.

Soil analyses have shown (Table 1) that in Manitoba the salinized soils contain sulphate as the dominant anion, and calcium, magnesium, and sodium as the dominant cations. Owing to the abundance of magnesium sulphate in these soils, its high solubility, and its well-known toxicity toward cereals (6, and others), it seemed a very suitable material for use in the preliminary studies reported here.

Plate Culture Experiments. As far as the author is aware little experimental work has been done concerning the effect of high concentration of soluble salts on the growth of soil-inhabiting fungi. For this reason culture media composed of either potato-dextrose agar or Duggar's nutrient-salts agar as a base, and containing various predetermined amounts of magnesium sulphate, were prepared. Three cereal root-rotting fungi, *e.g.*, *Fusarium culmorum* (W.G.Sm.) Sacc., *Helminthosporium sativum* P.K. & B., and *Pythium arrhenomanes* var. *canadensis* Vanterpl. & Trusc. were grown on these media in order to determine the comparative tolerance of these fungi to magnesium sulphate. The cultures were maintained at room temperature (18–22° C.) and, after a period of ten days had elapsed, the data recorded in Table 2 were obtained.

TABLE 2.—THE EFFECT OF VARYING CONCENTRATIONS OF MAGNESIUM SULPHATE IN POTATO-DEXTROSE AND DUGGAR'S NUTRIENT-SALTS AGARS ON THE GROWTH OF THREE FUNGI. (AVERAGE DIAMETER IN CENTIMETERS OF DUPLICATE CULTURES AFTER 10 DAYS)

Concentration of $MgSO_4 \cdot 7H_2O$ in per cent	*F. culmorum*		*H. sativum*		*P. arrhenomanes* var. *canadensis*	
	Potato dextrose agar	Duggar's salts agar	Potato dextrose agar	Duggar's salts agar	Potato dextrose agar	Duggar's salts agar
0.0	8.8	—	4.8	—	9.0	—
0.4	8.6	9.5	4.1	1.3	9.0	6.5
1.0	8.9	8.4	4.2	0.8	9.0	1.9
2.0	9.0	8.2	4.4	0.8	9.0	0.0
4.0	9.0	5.9	3.6	0.7	9.0	0.0
6.0	9.0	5.5	5.6	0.5	9.0	0.0
8.0	9.0	4.6	5.6	0.4	9.0	0.0
10.0	9.0	4.4	4.2	0.3	9.0	0.0

It is evident from Table 2 that, in the nutrient-salts agar, large amounts of magnesium sulphate reduced or prevented growth in the fungi listed above, but that no reduction of growth occurred on potato-dextrose agar. It is significant, however, that the two common root-rotting fungi, *F. culmorum* and *H. sativum*, grew comparatively well on potato-dextrose agar at all the salt concentrations used. These fungi exhibited a high tolerance to magnesium sulphate.

To ascertain if cereal seedlings and the two above-mentioned fungi responded similarly to high concentrations of magnesium sulphate, sterile seeds of wheat were planted on nutrient-salts agar containing various percentages of this salt. Five seeds were placed on one side of the culture plate while the other side was inoculated with *H. sativum* or *F. culmorum*. The test was repeated with barley. After a period of ten days it was found again that both fungi grew well at all concentrations used, while barley seed failed to germinate at concentrations of magnesium sulphate higher than 5%, but wheat seed did not germinate at concentrations higher than 3%. It was therefore established that the two root-rotting fungi were much less affected than the two cereals by high concentrations of magnesium sulphate.

Experiments with Soil. An attempt was made to ascertain if, by using salinized field soil results similar to those of the plate-culture trials would be obtained. Soil containing 6.71% of soluble salts was used in this experiment. From one half of this soil the salts were leached out by water percolation. The leached and the original soil were subsequently divided into two parts, one of which was artificially infested with *Fusarium culmorum* and the other left uninfested. The soil was put into one-gallon crocks and 50 seeds of barley were planted in each jar. After one month the seedlings were removed from the soil, weighed, and examined individually for root-rot infection. The averages from four replicates of this test are recorded in Table 3.

Table 3.—The effect of highly salinized and leached soil on seedling growth and development of root rot, caused by *F. culmorum* in barley. (Average results of four replicates)

Kind of soil	Treatment of soil	Green weight in grams	Disease rating
Leached	Infested with *F. culmorum*	30.0	7.4
	Not infested	44.6	10.6
Not leached	Infested with *F. culmorum*	23.2	4.8
	Not infested	29.8	5.0

On the basis of field observations, it was expected that, in the leached soil, a more vigorous growth and less disease would occur than in salinized (not leached) soil, as in the former soil the excess salts were removed. It was also expected that severe disease would develop in the soils that had been artificially infested, particularly in the salinized one. In the above experiment, however, only the expectation regarding seedling growth was realized: the other results were contrary to the expected.

For purposes of further investigation the soil used in the preceding experiment was utilized again: the leached soils—infested and not infested—were mixed to form one lot, and the same procedure was followed with the salinized soils to form a second lot. Each lot was divided into two parts. To one part of each lot a complete fertilizer (NPK—50 cc. of 1% solution per gallon of soil) was added. The other part of each lot served as a control. Afterwards, the soil was placed in clean one-gallon

jars and 50 seeds of barley were planted in each jar. The results of this experiment are summarized in Table 4.

TABLE 4.—INFLUENCE OF FERTILIZER ON SEEDLING GROWTH IN BARLEY AND ON INCIDENCE OF ROOT ROT IN LEACHED AND SALINIZED SOIL. (AVERAGE OF FOUR REPLICATES)

Soil type	Soil treatment	Seedling emergence	Green weight	Healthy plants	Diseased plants
		Per cent	Grams	Per cent	Per cent
Leached	Fertilizer (NPK)*	49.0	57.4	69.3	30.6
	Control	65.0	14.8	9.2	90.7
Salinized	Fertilizer (NPK)*	85.0	43.4	87.0	13.0
	Control	97.0	13.7	91.7	8.2

* The complete fertilizer was made up of equal parts, by weight, of ammonium nitrate, potassium sulphate, and calcium superphosphate.

The results in Table 4 confirm those presented in Table 3, and show that, in the highly salinized soil, as compared with the leached soil, the green weight of plants was reduced, as was also the amount of root rot. The addition of fertilizer increased green weight, and, in the case of the leached soil, appreciably reduced the amount of root rot. The plants grown in the leached soil to which no fertilizer was added suffered the most root rot injury.

It is difficult to account for the discrepancy between the amount of root rot occurring in the salinized soil used in green house experiments and that found in salinized field soil. It had been noticed in field surveys, however, that, in salinized fields where root-rot attack was particularly severe, the soluble salts were concentrated near the soil surface. It was thought probable that, as, in the greenhouse, pots of soil were usually watered from the top, the soluble salts in greenhouse soil were not allowed to collect at the surface, and therefore the method of watering was faulty and not altogether comparable to field conditions.

An experiment was designed to test the effect of different methods of watering pots on the growth of cereals in salinized soil. Three sets of pots of such soil were prepared, the first set being watered only from the top, the second set only from the bottom, and the third receiving water alternately from the top and bottom. Wheat, oats, and barley plants were grown to maturity in these pots. At the end of the experiment it was found that watering the pots alternately from top and bottom resulted in the most vigorous plant growth, while the application of water from the bottom was distinctly harmful, as the plants remained stunted, bore small inflorescences, and were most severely attacked by root-rotting fungi. The sub-irrigation method of watering the pots most closely reproduced the plant condition found in salinized fields, and it was therefore used in subsequent experiments with soil in these studies.

To study the effects of the addition of pre-determined amounts of magnesium sulphate to leached soil on the development of root rot in wheat and barley, one-gallon stone-ware jars were filled with leached soil to which various quantities of magnesium sulphate ($MgSO_4.7H_2O$) were

added. Previous to putting the soil into the jars three pints of distilled water were poured into each jar. This quantity of water, without further supplementation, was found sufficient for the growth of cereal seedlings for the period of one month. By following this procedure, it was found that the soluble salts contained in the soil rose to the surface in a way comparable to that in the field when soil moisture is abundant but rainfall inadequate. Fifty seeds of wheat infested with spores of *F. culmorum* were planted in each jar. The experiment was repeated with barley. Four weeks after the planting of the seed, data concerning seedling growth and intensity of root rot were obtained. These data are recorded in Table 5.

TABLE 5.—THE EFFECT OF ADDING VARIOUS QUANTITIES OF MAGNESIUM SULPHATE TO LEACHED SOIL ON THE GROWTH OF BARLEY AND WHEAT PLANTS, AND ON THE INCIDENCE OF ROOT ROT CAUSED BY *Fusarium culmorum*

Crop	Weight of $MgSO_4 . 7H_2O$ per gallon, in grams	Seed infested by *F. culmorum*				Control			
		Germination in per cent	Number diseased plants	Disease rating	Green weight in grams	Germination in per cent	Number diseased plants	Disease rating	Green weight in grams
Barley (Wisconsin No. 38)	0	92.0	37	23.8	43.2	94.0	15	10.0	42.8
	1	93.0	43	29.8	38.4	100.0	13	3.8	42.2
	10	92.0	50	36.2	31.1	95.0	12	8.0	41.1
	20	95.0	57	39.8	30.3	91.0	4	9.8	30.0
	50	83.0	63	52.8	25.3	97.0	16	7.6	35.3
Wheat (Mindum)	0	45	41	83.6	31.2	57	28	54.2	35.7
	1	37	33	88.0	28.3	50	36	64.4	34.9
	10	36	33	91.6	25.3	55	46	69.0	32.2
	20	39	36	90.6	16.2	60	37	57.4	27.1
	50	39	36	85.0	13.7	55	38	62.4	18.4

The disease-rating data given in Table 5 show that Mindum wheat was more susceptible to *F. culmorum* root rot than was barley. In barley, however, the influence of increasing amounts of magnesium sulphate on the amount of disease was very clearly marked, while in wheat this was not so. In both varieties the total green weight of plants was reduced as the amount of salt was increased, no matter whether the seed had been infested with spores of the fungus or not.

Sand Culture Experiments. With a view to ascertain the influence of magnesium sulphate on the intensity of seedling infection caused by *F. culmorum* in cereals under conditions in which the environment could be controlled as far as possible, the sand-culture method of growing the plants was used. As containers for the sand one-quart glass jars, suitably masked to exclude light from the roots of the plants, were employed. Into each jar was poured a predetermined quantity (250 cc.) of Knop's solution. In this nutrient medium the amount of magnesium sulphate was varied according to need, so that the range of concentrations of this salt extended from 0.0143% to 0.4290%. The jars were then filled with washed white sand. Ten surface-sterilized seeds were planted in each jar. Duplicate plantings with seed which was artificially infested with *F. culmorum* were

also made. In this way three varieties of cereals, Mindum wheat, Victory oats, and Wisconsin Selection No. 38 barley, were tested. Two pots of each type of seed and nutrient solution constituted the experiment. The seedlings were removed from the sand after a growth interval of two weeks, and the intensity of root rot on the individual plants was determined. The results of this experiment are given in Table 6.

In this experiment, although the plant populations were small and the results are subject to considerable experimental error, yet the data presented in Table 6 indicate a definite trend in the amount of disease developed in the seedlings grown on different concentrations of magnesium sulphate.

TABLE 6.—THE EFFECT OF VARIOUS CONCENTRATIONS OF MAGNESIUM SULPHATE ON THE DEVELOPMENT OF ROOT ROT CAUSED BY *F. culmorum* IN SEEDLINGS OF WHEAT, OATS, AND BARLEY

Concentration of $MgSO_4 \cdot 7H_2O$ in per cent	Percentage of plants diseased								
	Wheat (Mindum)			Oats (Victory)			Barley (Wis. No. 38)		
	Control	Infested seed		Control	Infested seed		Control	Infested seed	
0.0143	0.0	85.0	Mean 74.0	0.0	60.0	Mean 57.0	0.0	65.0	Mean 76.0
0.0286	0.0	50.0		0.0	40.0		0.0	85.0	
0.0572	0.0	65.0		0.0	60.0		0.0	80.0	
0.1144	0.0	80.0		0.0	55.0		0.0	75.0	
0.1716	0.0	100.0		0.0	70.0		0.0	75.0	
0.2288	0.0	90.0	Mean 87.0	0.0	60·0	Mean 65.0	0·0	75.0	Mean 84.0
0.2860	0.0	90.0		0.0	50.0		0.0	90.0	
0.3432	0.0	85.0		0.0	75.0		0.0	95.0	
0.4004	0.0	95.0		0.0	70.0		0.0	85.0	
0.4290	0.0	75.0		0.0	70.0		0.0	75.0	

Owing to the fact that the growth of seedlings in all jars, except those containing the highest concentration of magnesium sulphate, was normal, the experiment was repeated, but the range of concentrations of the salt was extended from 0.0143% to 2.574%. The results of the expanded test are given in Table 7. They show quite clearly that high concentrations of magnesium sulphate in the culture solution increased the disease rating in the seedlings arising from artificially-infested seed, and adversely affected seedling growth, as defined by the total green weights. Seed germination was not seriously affected by the salt at any of the concentrations used.

DISCUSSION

There is, apparently, a close relation between high salinity of the soil and severe attack of cereals by root-rotting fungi. The nature of this relation is not fully understood. The results of the present study show, however, that cereals are more or less adversely affected by high salinity of the soil, while such common root-rotting fungi as *Helminthosporium sativum* and *Fusarium culmorum* are not. It is reasonable to assume, therefore, that cereals growing in saline soil become predisposed, due to a weakening of the plants, to attack by these fungi.

TABLE 7.—FURTHER DATA ON THE EFFECT OF VARIOUS CONCENTRATIONS OF MAGNESIUM SULPHATE IN SOLUTION ON THE DEVELOPMENT OF ROOT ROT IN CEREAL SEEDLINGS AND ON THEIR GROWTH

Crop	Concentration of $MgSO_4 . 7H_2O$ in per cent	Seed infested by *F. culmorum*			Control		
		Germination in per cent	Disease rating*	Total green weight in grams	Germination in per cent	Disease rating*	Total green weight in grams
Wheat (Mindum)	0.0143	85.0	70.5	5.4	95.0	1.0	10.9
	0.4290	60.0	80.0	2.6	95.0	0.0	9.0
	0.8350	45.0	85.5	2.9	90.0	0.0	5.1
	1.2870	60.0	89.3	2.1	75.0	5.3	3.6
	1.6760	70.0	88.0	2.0	100.0	6.0	2.7
	2.1450	40.0	91.5	1.0	95.0	4.2	2.7
	2.5740	40.0	92.4	1.0	80.0	37.5	2.0
Oats (Victory)	0.0143	100.0	13.0	11.5	85.0	1.1	11.4
	0.4290	85.0	43.0	7.7	100.0	0.0	9.5
	0.8380	95.0	31.0	5.2	100.0	0.0	7.0
	1.2870	95.0	57.3	3.1	95.0	0.0	4.5
	1.6760	100.0	64.0	2.8	100.0	2.0	3.1
	2.1450	100.0	47.0	2.3	90.0	0.0	2.5
	2.5740	90.0	64.2	2.1	85.0	0.0	1.7
Barley (Wisconsin No. 38)	0.0143	100.0	6.0	13.4	100.0	0.0	12.9
	0.4290	80.0	21.5	9.5	95.0	0.0	7.5
	0.8380	95.0	4.2	6.6	90.0	0.0	5.5
	1.2870	80.0	15.5	4.4	90.0	0.0	4.5
	1.6760	95.0	16.8	4.1	75.0	0.0	2.5
	2.1450	85.0	31.1	2.6	90.0	0.0	2.4
	2.5740	85.0	26.3	2.7	95.0	0.0	2.5

* The Disease ratings were determined on the basis of amount of disease in the emerged seedlings.

Salinity of the soil in any particular horizon is not constant: the location of the maximum concentration of salt is governed by the upward or downward movement of soil water. When the upward capillary flow is greater than the downward percolation of rain-water, the salts in the soil solution gradually rise to the surface; in periods of abundant rainfall, the salts are carried deeper into the soil.

The cereal crop appears to be most adversely affected when the soluble salts in the soil are deposited near the soil surface, that is, in the region of the root crowns. Under these conditions exosmosis probably plays an important rôle, and the plants suffer from "physiological drought". When this happens, the resistance of the plant to attack by root-rotting fungi appears to be very weak. Since sodium carbonate is not present in Manitoba, corrosive action on the roots and stems of cereals cannot be said to play an important part in the development of the initial stages of root rot; but it is probable that, when soluble salts are concentrated in the region of the root crowns, the cells in the crowns and stem bases become plasmolyzed, in which case death of these cells may occur. The dead cells are easily invaded by soil fungi, among which root-rotting fungi are included and the advanced stages of root rot subsequently develop.

As in Manitoba the autumn and spring precipitation is usually sufficient to wash toxic salts that may be present near the surface of the soil

some distance down into the soil, the germination of seed in the spring is seldom affected. In the summer, however, particularly when rainfall is inadequate, these salts rise to the surface, and their presence is harmful to the growing crop. The plants may become adversely affected by the salts at any stage of plant growth, the injury occurring when the salts in the surface horizon reach a toxic concentration.

Experimentation on this problem is difficult. If the experimental work is to be done under field conditions a great expenditure of labour and apparatus is required to control, partially at least, the environment. In the greenhouse one cannot duplicate conditions found in the field. Experimentation can therefore be only limited in its scope, and the experiments are subject to a great number of uncontrollable errors. It is probable that the best method of studying the problem is to make numerous field observations, supplemented where possible by greenhouse or laboratory experiments.

SUMMARY

Common root rot of cereals, caused by species of *Fusarium* and *Helminthosporium*, is widespread in Manitoba, but the disease is intensified when these cereals are grown in soil which contains a considerable admixture of soluble salts. In such soil the plants remain dwarfed, the basal leaves shrivel, and tillering is reduced. Death of the plants generally occurs unless rain-water carries the excess soluble salts below the region of the root crowns.

Laboratory experiments have shown that both of these root-rotting fungi are able to grow comparatively well on media containing concentrations of magnesium sulphate sufficient to prevent seed germination in wheat and barley. Sand-culture experiments, and experiments with leached soil containing different amounts of magnesium sulphate have demonstrated further the tolerance of the above fungi to this salt. These experiments also have shown that high concentrations of the salt retarded seedling growth and increased the severity of root rot.

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Résumé

Recherches préliminaires sur l'effet exercé par une salinite excessive du sol sur la fréquence des pourritures des racines des céréales. J. E. Machacek, Laboratoire fédéral de recherches sur la rouille, Winnipeg, Man.

La pourriture commune des racines des céréales, causée par les espèces *Fusarium* et *Helminthosporium*, est très répandue au Manitoba, mais elle est d'une gravité exceptionnelle sur les sols contenant une proportion considérable de sels solubles. La végétation reste rabougrie dans ces sols, les feuilles de base se racornissent, le tallage est réduit et les plantes meurent généralement à moins que l'eau des pluies n'entraîne l'excès de sels solubles au-dessous de la région où se trouvent les collets des plantes. Des expériences conduites au laboratoire ont fait voir que ces deux espèces de champignons qui causent la pourriture peuvent se développer relativement bien sur des millieux contenant des concentrations de sulfate de magnesium suffisantes pour empêcher la germination des semences de blé et d'orge. La tolérance de cryptogame à ce sel a été démontrée également par des essais de culture sur sable et des recherches sur sol lessivé. Ces mêmes expériences ont fait voir en outre que de hautes concentrations de sel retardent la végétation des plantes et augmentent la gravité de la pourriture.

STUDIES ON RHIZOCTONIA SOLANI KÜHN.

I. EFFECT OF POTATO TUBER TREATMENT ON STEM INFECTION SIX WEEKS AFTER PLANTING[1]

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During recent years there has been a tendency among observers to discount the efficacy of tuber treatment in view of the general and frequently heavy natural infestation of the older cultivated soils by *Rhizoctonia Solani*. This is because a considerable amount of sclerotia often forms on the tubers, or they are misshapen despite treatment. It also appears that neither the actual effects on yield from the attack of the pathogen on the stem and stolons at different periods, nor the factors which favour sclerotia formation are sufficiently well understood.

In this report the effect of treatment, under a wide range of field conditions and soil types, was studied in relation to stem infection from clean treated tubers versus untreated tubers heavily infested with sclerotia, 42 days after planting. A related report dealing with the effect on yield and infection subsequent to this period will be available later.

A review of the literature on treatment of potato tubers to control stem canker does not appear necessary in this paper, since, with the possible exception of Goss (2), the conclusions reached by others have not been based on stem lesions before harvest, but on final yield and infection data, or on the sclerotia present. Schaal (3) used stem lesions 44 days after planting to determine the effects of soil temperature on the disease. Dana (1) has given a fairly comprehensive review of the literature to 1925.

MATERIALS AND METHODS

Location of Experiment and Soil Type

The experiments were located on various farms in the vicinity of Edmonton, on the experimental plots at the University of Alberta, Edmonton, and at the following Dominion experimental farms: Kentville, N.S.; Fredericton, N.B.; Ste. Anne de la Pocatiere, Que.; Indian Head, Sask.; Lacombe, Alta.; and Saanichton, B.C. While this study has been more or less confined to the soil type common in Western Canada, it has been possible in six of the thirty-four cases reported to place the experiment on soils of glacial origin in Nova Scotia, New Brunswick, Quebec and British Columbia, viz.: experiments Nos. 9, 10, 11, 21, 22, 33 and 34. The soil type and previous crop at each location are, where possible, listed in Table 1.

Variety and Treatment

In all tests but one the variety used was Early Ohio, since it is very susceptible to stem canker, and sclerotia readily form on the tubers. With one or two exceptions, the stock each year was supplied from one source, treated, and distributed to each location. The tubers requiring treatment

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[3] Associated with Department of Field Crops.

TABLE 1.—RESULTS OF 34 TESTS ON THE EFFECT OF TREATMENT OF POTATO TUBERS TO REDUCE STEM CANKER CAUSED BY *Rhizoctonia Solani* SIX WEEKS AFTER PLANTING

Year and experiment	Average severity stem lesions %			Z† value	Plants, clean stems, %				No. hills missed			Previous crops or summerfallow	Soil type‡	Location
	A	O	X		A	O	X	*	A	O	X			
1933														
1	28.9	31.2	29.5	—	12	9	15	3	1	0	2	S.F.** (garden)	B	University, Edmonton
2	17.7	18.3	16.7	—	24	9	19	5	5	2	4	S.F.** (garden)	B	University, Edmonton
3	17.2	31.0	19.1	1.22	29	15	15	14	5	2	1	S.F.** (garden)	B	University, Edmonton
4	3.2	6.8	20.5	1.79	41	34	25	16	4	1	1	Sod (*Agropyron* sp.)	B	University, Edmonton
5	2.5	7.0	6.1	.66	46	24	22	24	1	2	1	Virgin prairie sod	B	Clover Bar, Alta.
6	0.7	2.3	17.0	1.72	81	80	39	42	4	0	1	Wheat (old soil)	B	St. Albert, Alta.
7	9.4	17.0	11.7	.74	42	35	36	6	5	2	3	Wheat	G	Fallis, Alta.
8	3.5	4.6	10.0	1.02	76	70	36	40	0	1	5	Wheat	B	Indian Head, Sask.
9	1.4	5.3	11.8	1.20	84	79	53	31	5	3	6	?	G	Saanichton, B.C.
10	0.8	1.6	6.5	1.12	95	85	58	37	2	3	7	?	G	Ste. Anne de la Pocatiere, Que.
11	2.9	7.6	11.9	1.13	71	70	44	27	0	0	5	Mixed hay sod	G	Kentville, N.S.
1934														
12	6.9	1.6	5.9	.64	74	89	63	11	0	0	0	S.F. 2 yrs. (garden)	B	University, Edmonton
13	.4	1.0	3.5	.27	80	84	65	15	0	0	0	S.F. 2 yrs., cereals	B	Lacombe, Alta.
14	.3	.9	4.0	.26	90	89	69	21	3	0	1	Truck (hog manure)	B	North Edmonton
15	4.1	2.2	13.6	.13	69	77	54	15	0	4	5	S.F. 2 yrs.	B	St. Albert, Alta.
16	3.3	3.0	17.3	1.66	62	60	31	31	3	2	3	S.F. 2 yrs.	B	St. Albert, Alta.
17	11.0	19.1	31.1	1.25	23	20	7	16	8	3	8	Potatoes	B	St. Albert, Alta.
18	17.7	12.9	16.0	.01	35	35	21	14	3	0	2	Oats	G	Fallis, Alta.
19	3.5	2.1	18.7	1.32	57	60	31	26	2	0	7	Oats, clover	B	Duffield, Alta.
20	2.4	3.1	1.4	.10	71	64	61	10	0	0	0	Potatoes, prairie sod	B	Clover Bar, Alta.
21	3.2	2.7	36.4	2.24	85	89	24	61	0	0	0	Oats	G	Kentville, N.S.
22	.2	.8	3.4	—	98	97	73	25	–	–	–	?	G	Fredericton, N.B.

1935														
23	1.4	8.7	31.2	2.02	97	51	16	81	0	1	1	S.F. 3 yrs. (garden)	B	University, Edmonton
24	.9	7.4	25.1	2.10	86	70	36	50	2	0	0	S.F. 3 yrs. (garden)	B	University, Edmonton
25	4.3	6.4	21.7	1.90	63	57	18	45	0	2	1	S.F. 3 yrs. (garden)	B	University, Edmonton
26	3.4	14.9	33.6	2.04	64	41	13	51	0	0	0	S.F. 3 yrs. (garden)	B	University, Edmonton
27	10.9	11.6	15.0	.20	65	59	51	14	2	0	0	Truck	B	North Edmonton
28	3.8	2.6	8.7	.88	88	85	67	21	3	3	3	Potatoes	B	North Edmonton
29	5.8	6.6	23.3	1.59	77	79	46	31	1	3	3	Oats, potatoes	B	St. Albert, Alta.
30	1.7	6.1	9.0	.95	91	64	60	31	8	1	0	S.F., grass	B	Lacombe, Alta.
31	.7	4.2	6.9	.95	96	78	72	24	3	1	4	Cereals, 2 years	G	Fallis, Alta.
32	.1	1.2	6.6	.29	99	90	67	32	2	0	3	Wheat, 2 years, prairie sod	B	Duffield, Alta.
33	.8	1.0	24.0	2.13	95	93	70	25	2	0	3	Lamb's quarters	G	Kentville, N.S.
34	.2	4.5	29.7	2.27	98	81	17	81	0	1	6	Hay and pasture, 5 yrs.	G	Lulu Island, B.C.
Average					67	63	42	28.7	2.3	0.9	2.5			

† "Z" value of 0.6 or higher regarded significant.

‡ B. Black organic loam. G. Glacial origin.

* The decrease in per cent clean plants in the "X" series over that in the "A" series.

** Summerfallow.

were immersed for five minutes in 1 : 500 $HgCl_2$ solution to which one per cent, by volume, of hydrochloric acid was added. Only clean tubers were used for the treated series. This removed any question of there being viable sclerotia after treatment.

Outline of Experiment and Method of Taking Data

Uniformity was maintained throughout with regard to order of planting and method of rating for disease severity. There were, in each experiment, three series or sections, which are indicated by the three letters "A", "O" and "X". The tuber sets of the A series were clean and disinfected, as already indicated, before planting. Those of the O series were apparently free from scurf, and were not disinfected, while to the sets of the X series adhered a large number of viable sclerotia. The sets of the X series were not treated. Thus, in each experiment there were 100 sets in the A series, and a like number in each of the O and X series. Randomization of the A, O and X hills throughout was maintained. About six weeks after planting, when the plants were about eight to ten inches high, each stalk was pulled and the underground part of the stem, with its proper number attached to its label, forwarded or taken to this laboratory, where the rating was done by one person.

The relative severity of disease on the stalk of each plant was indicated numerically. A stem with one or two slight, superficial lesions was rated 0.3, 0.5 or 0.8. Values from 1 to 4.5 were given according to number and depth. No cases with values indicated were considered as very serious. A value of 5 was allotted to those instances where the terminal bud had been destroyed, even if the other areas of the stem were sound. Infections involving both terminal bud and sprout received proportionately higher values up to 10 where the sprout was killed.

The data for each of the thirty-four tests, based on numerical ratings, were analysed by the analysis of variance method, and the Z value for significance of treatment in each case determined from Fisher's Tables. In addition to the analysis indicated, the percentage of plants in each series free from stem lesions is listed, because these data provide a second basis for arriving at the value of treatment. They also indicate the degree of infection arising from the natural infestation of the soil, as registered in the A series in each test. By allowing for this, the percentage of plants infected, for which the abundant viable sclerotia on the X series were responsible, can be readily calculated. Obviously, both methods are very imperfect in accurately indicating either the severity of the disease or the actual transfer of the pathogen from set to stem.

RESULTS

During each of the three years, the disease ratings listed in the second, third and fourth columns of Table 1, are, in general, least in the A series, and greatest in the X series. In seven instances, the ratings in the A series are approximately as great as they are in the X series, which is the result of a heavy natural infestation of the soil. As determined by the Z value, the rating of the X series was significantly greater than that of the corresponding A series in twenty-four tests, viz.: Nos. 3 to 12, inclusive; 16, 17, 19, 21; and 23 to 35, omitting 27 and 32.

The importance of the hyphae on the apparently clean untreated sets of the O series is indicated by the numerical rating in the third column of Table 1. In general, there appears a tendency for the numerical rating to be increased over that in the corresponding A series. Thus, omitting the nine experiments Nos. 1, 2, 3, 7, 12, 17, 18, 27 and 29, where a heavy natural soil infestation prevailed, the increase in fifteen of the remaining twenty-five experiments is apparently significant, but probably not in the other ten cases. In certain instances, for example experiments Nos. 9, 11, 23, 24, 25, 26, 31 and 34, the rating on the O series increased with that of the corresponding X series. But possibly this is a coincidence, since there are about an equal number of instances where there is either only a slight increase over the rating of the corresponding A series, or it is actually less, even though the rating on the X series is relatively high. On the other hand, one might expect environmental conditions which favour a high rating on the X series would also favour maximum disease expression from the hyphae of the pathogen on the untreated sets of the O series.

If the importance of sclerotia infested sets, and also of hyphae on apparently clean untreated sets, is determined on the basis of the percentage of plants having clean stems (columns six, seven and eight of Table 1) the results are, on the whole, fairly comparable to those obtained by the numerical rating method. The figures in column nine represent the percentage decrease over the corresponding A series of plants in the X series having clean stems. In all experiments, except No. 1, decreases which range from 5% upwards as high as 81% occurred, although most of these were between 14 and 31%. The average decrease was only 28.7%. The marked variability indicated will be referred to later.

The significance of the hyphae on the apparently clean tubers (O series) may be estimated by excluding experiments Nos. 1, 2, 3, 7, 12, 17, 18, 27 and 29, where the infestation of the soil was heavy. In eight of the remaining 25 experiments, viz.: Nos. 5, 10, 23, 24, 26, 30, 31 and 34, the decrease in percentage of plants having clean stems over the corresponding A series was 22, 10, 46, 16, 23, 27, 18 and 17, respectively. In another six cases the decrease was between 5 and 9%, and in seven, between 1 and 3. However, in six experiments, viz.: Nos. 12, 13, 15, 19, 21 and 29, there were actually more clean stems in the O series by 15, 4, 8, 3, 4 and 2%, respectively, which indicates that those cases below 8% may not be significant. Even so, in all but 7 cases out of the 34, there was a higher percentage of stems with lesions in the O series than in the corresponding A series.

With regard to a possible correlation between previous crop sequence or summerfallow for one, two and three years, the ratings in the A series do not indicate either a positive or a negative trend. For example, an average rating of 2.5% occurred in virgin soil (expt. 5); 0.1 following the second crop of wheat after breaking (expt. 32); 0.3, one year, in old truck soil (expt. 14); and in the following year on an adjacent strip of the same soil (expt. 27), a rating of 10.9%. Finally, in experiments 17, 18, and 28, ratings of 11.0, 17.7 and 3.8% occurred after potatoes, oats and potatoes, respectively. The heavy infestation of the soil after one year of summerfallow in experiments 1, 2 and 3 was in soil used for a garden for about ten years. After two years of summerfallow of this garden soil, the infesta-

tion index dropped to 6.9 (expt. 12), and after the third year of summer-fallow it was 1.4, 0.9, 4.3 and 3.4% (expts. 23 to 26). There was a basic, although variable, and in certain cases apparently slight, infestation in all soils used in the tests, regardless of whether they were of glacial origin or the black organic loam type.

Of interest is whether the transfer of the pathogen from the sclerotia to the stem was uniform each of the three years. The data in column four of Table 1 indicate that in 1934 there were more than twice as many cases of low effectiveness, measured by severity of infection, than in either 1933 or 1935. If judged on the basis of the decrease in percentage of plants having clean stems (compare columns six and nine of Table 1) the effectiveness is again lowest in the 1934 experiments. Obviously, cases of high soil infestation were not included in these comparisons. Data are not available to determine whether the variability indicated was due to environmental factors of the year or to differences in relative prevalence of virulent strains on each of the three seed lots used. The possible effects of these factors will be discussed later.

The effect of the treatment, and also of the disease from the sclerotia in causing missing hills is indicated under A and X in columns ten and twelve of Table 1. This is compared with the missing hills from the apparently clean untreated sets under O, column eleven. Obviously the treatment used caused approximately as many missing hills as the disease from sclerotia on the sets of the X series did, while approximately one-half as many missing hills occurred on the O series. The average for all experiments, in each case, was 2.3, 2.5 and 0.9%, respectively.

DISCUSSION

In evaluating the results presented in this paper, it must be kept in mind that the disease data were secured when the plants were about eight inches high, approximately six weeks after planting, and, therefore, apply to this stage only. Any correlation which the extent of injury to the stem during this stage may have with total yield, condition of tubers, amount of sclerotia on them, and other subsequent disease symptoms, is to be considered later in the light of another but related set of data taken at harvest. The effect of treatment is based on treatment of clean tubers versus untreated tubers bearing a uniformly heavy infestation of sclerotia. Finally, any infestation on the treated series had its origin in the soil, and not from the set.

Some of the more obvious inconsistencies of the experimental data should be mentioned. For example, the numerical rating used is more likely to indicate the degree of injury to the sprout than the amount of transfer of the pathogen from the scurfy set to the stem. This may be misleading because a single lesion on the terminal bud usually destroys it, and the case calls for a rating which is disproportionately high to that given those lesions on the sides of a sprout, which lesions, although often numerous, and in many cases healing completely, remain incipient, with no serious damage to the plant. This difficulty has been partly overcome by the data based on the percentage of plants free from lesions. Thus, the increase of infection in the untreated series over that of the treated series in each experiment would seem a simple and fairly accurate index of the

effective transfer of the pathogen from the set to the stem, and, therefore, an indication of what, in general, can be expected from an effective treatment under a given set of conditions.

There was marked variability among the different experiments, both in degree of injury to the stem and in amount of transfer of the pathogen from the set to sprout. Fluctuations due to differences in effective soil infestation were expected, but, barring adverse environmental factors, there should have been a fairly uniform transfer from the heavily infested sets, after allowing for soil infestation. If a deduction is made for the percentage of plants infected from the soil, we find in the thirty-four experiments an average of only 28.7% of them infected from this source. This figure is based on approximately 3,400 plants in the X series. The variations, however, were wide. In five experiments it was between 3 and 11%; in twenty-two cases between 14 and 35%; in five, between 40 and 51%; and in the remaining three cases it was above this, being at Kentville, Nova Scotia, in 1934, 61%, and at Edmonton, Alberta, and Lulu Island, British Columbia, 81% in 1935. Thus, it would appear from our experiments that, under average field conditions, lesions are likely to occur at the six-weeks stage on approximately 30% of the plants from sclerotia on the sets, and in certain cases it may be much greater, or much less. With regard to the factors causing variation, there is record of only one or two antecedent crops for each location (Table 1, column 13), and no data on the actual soil infestation by *R. Solani*, or on the relative prevalence of virulent and non-virulent strains in the soil or on the tubers. With two possible exceptions, the factors of temperature and moisture were apparently very favourable during the six weeks of the test. The former varied between 16° and 20° C., while the latter approximated that considered about optimum for plant growth. Both factors seemed well within the range for good infection under laboratory experimental conditions.

With regard to the effect of a previous crop or cultivation on the effective infestation of the soil, the results of these experiments do not provide reliable information for or against the possibility. To study this under field conditions would require far more replication and control of the many variables than was possible in a purely incidental phase of the main experiment. Also, in a study of this kind attention should be paid to the initial as well as to the final effective soil infestation, which obviously involves the relative prevalence of virulent and non-virulent strains of *R. Solani*. This is illustrated by experiments 1, 2 and 3 (Table 1), where, after one summerfallow, the infestation was still very effective, and continued to remain fairly effective despite a second and third year of summerfallow (expts. 12, 23, 25 and 26, Table 1). Subsequent data show that even after four years of summerfallow it was nearly as effective as it was the first year. Moreover, the results indicate that in ordinary field procedure there is often apt to be as much lesioning of the potato stems following one or two crops of cereals as there is after a truck crop, or potatoes. From other data there is no doubt that this is so in the case of sclerotia formation on the tubers. On the other hand, many feel that a soil is more readily polluted with virulent strains of the pathogen by several successive crops of potatoes, than by other crops. The rate of increase would depend,

among other factors, on whether virulent strains were added by way of the tubers planted, and on the degree to which virulent strains, already in the soil, prevailed. Hence, it is conceivable that a summerfallow, cereal or other crop may not always materially change either the total or the effective infestation during one year. These experiments apparently support this view, and until more accurate information on the saprophytic behaviour of *R. Solani* in normal cultivated soils is available, final statements on the beneficial effects of a given crop cannot be made.

The data may now be examined for beneficial effects of treatment in reducing stem lesions originating during the first six weeks from sclerotia on the sets. By the numerical rating method, the severity of the lesions in the X series was, by statistical analysis, significantly greater than on the stems of the A series (from clean treated sets) in 24 out of 34 experiments (Table 1), or 70% of the cases. If the comparison is made by the second method, viz.: the percentage of plants in the X series which had no lesions on the stem, and allowance made for the plants infected from the soil, as indicated by the A series, the results are, in general, comparable to those arrived at by the first method. For instance, there were, including only those cases with increases of 10% or greater, 31 instances out of 34, or 90% of them, where treatment was valuable to a greater or lesser degree in reducing the number of plants having lesions on the stem at this stage. If the nine experiments where the soil carried a heavy infestation are excluded, there were 26, or 76% of all experiments with values above 10%. In general, the measure of control from treatment possible under field conditions is limited by the effective natural soil infestation. But it should be noted that in six experiments, viz.: Nos. 5, 12, 13, 14, 15 and 20, where treatment was either not significant, or barely so, by the numerical rating method, the natural soil infestation was apparently very light.

With regard to the effect of planting apparently clean untreated tubers, the evidence secured, while in many cases indefinite, indicated a general tendency for increased infection of the stems from the material used. But, obviously this conclusion should not be applied to all lots of apparently clean tubers without further experimental evidence secured from sufficient samples to be representative. If the hyphae of *R. Solani* on tubers are, in general, really important in increasing the disease, immersion for a brief period in an inexpensive formaldehyde solution, or possibly a simple dust treatment would give the necessary protection. But if found unimportant the value of certified seed is enhanced by at least the cost of treatment by mercurials, and by the frequent detrimental effect of some of them on yield (1).

In view of the marked tendency for so many of the early stem lesions to heal without apparent injury to the stem, it would seem essential to study the disease during subsequent stages on the stolons, and its real effect on yield, and to evaluate each separately from that arising from soil infestation.

Finally, a general conclusion regarding the question of the effect of the treatment used, versus disease, in causing missing hills, cannot be arrived at by the data at hand. Apparently each factor caused approximately equal amounts in these experiments, but whether similar results would be

obtained with other seed lots, or by a less concentrated solution, or by an unacidified solution, is a matter for further study. Information on the effects of different mercurial treatments on the viability of tubers stored or planted under different environmental conditions is needed.

SUMMARY

The effects of treating potato tubers with mercuric chloride solution, acidified, and the transfer of *Rhizoctonia Solani* to the stems from clean treated tubers versus untreated tubers heavily infested with sclerotia was studied under a wide range of field conditions, which included different crop sequences, culture and soil types. The effect, as indicated on the stems 42 days after planting, was recorded by a numerical rating for severity of lesions, and also by the percentage of plants without lesions. In 24 out of a total of 34 experiments (70%) the severity of infection was significantly greater on the plants from untreated sets heavily infested with sclerotia than on those from clean treated sets. On the basis of percentage of plants with clean stems, in 31 experiments, or 91% of them, an effective treatment would have been valuable at this stage. There was a tendency for increased infection arising from apparently clean untreated sets. All soils, regardless of whether the previous crop was summerfallow, cereals, truck, or potatoes, or whether of glacial origin or the black prairie loam type, carried a basic, although variable infestation. In the 34 experiments, an average of 28.7% of the stems of plants from sets with a heavy infestation of sclerotia, had lesions attributable to the sclerotia, and if the amount for which the soil infestation was responsible is included, the average was only 42%. Extreme variability, which could not be accounted for in the transfer of the pathogen to the stems from heavily infested sets, was common during the three years of the test. The treatment used apparently caused as many missing hills as the pathogen from the sclerotia did, which average per experiment was approximately 2.5.

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Résumé

Recherches sur la rhizoctonia solani kuhn. 1. Effet du traitement des tubercules sur l'infection de la tige six semaines après la plantation. G. B. Sanford, Laboratoire fédéral de pathologie végétale, Edmonton, Alta.

L'effet du traitement des tubercules de pommes de terre avec une solution de chlorure de mercure acidifiée, et la transmission du *Rhizoctonia Solani* aux tiges du pied, au moyen du tubercules traités et sains et de tubercules non traités et fortement infectés de sclérotes, a été étudié sous différentes conditions de grande culture qui comprenait différentes sucessions de récoltes, différents modes de culture et différents types de sols. L'effet, indiqué sur les tiges quarante-deux jours après la plantation, a été noté au moyen d'un chiffre numérique indiquant la gravité des lésions ainsi que le pourcentage de pieds sans lésions. Dans 24 des 34 expériences (70 pour cent du total) la gravité de l'infection était beaucoup plus grande sur les pieds provenant de plantons non traités et fortement infestés de sclérotes que sur ceux provenant de plantons propres et traités. Sur la base du pourcentage de pieds à tiges propres, dans 31 expériences, ou 91 pour cent du total, un traitement efficace aurait été utile à cette phase. L'emploi de plantons apparemment propres mais non traités tendait à accroître l'infection. Tous les sols, quelle que fût la récolte précédente, jachère, céréales, légumes ou pommes de terre, et aussi bien ceux d'origine glaciaire que les sols noirs de prairie, portaient infection, quoique en nombre variable. Dans les 34 expériences une moyenne de 28.7 pour cent des tiges de pieds provenant de plantons provenant fortement infestés de sclérote portaient des lésions attribuées aux sclérotes et si l'on ajoutait la quantité pour laquelle l'infection du sol était responsable, la moyenne n'était que de 42 pour cent. Une variation excessive et inexplicable dans le transfer du pathogène aux tiges provenant de plantons fortement infestés était commune pendant les trois années de l'essai. Le traitement employé paraît avoir causé autant de pieds manquants que la pathogène du sclérote; la moyenne d'après l'expérience était d'environ 2.5.

SEED REPRODUCTION IN THE DANDELION

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REPRODUCTION OF THE DANDELION

This investigation was undertaken in the spring of 1935, with the object of obtaining data as to the reproduction of the dandelion and the best measures for its control.

The dandelion, comprising the two principal species *Taraxacum officinale* and *Taraxacum erythrospermum*, has become a serious weed in lawns, parks, etc. in towns and suburban places generally, to such an extent that serious efforts for its control and, so far as possible, its eradication, are necessary. The plant belongs to the botanical family of the Compositae,—the highest family of the flowering plants, comprising some twenty-five species. All of the plants of this family are characterized by bearing numerous small flowers (called florets) on a disc or head, as in the sunflower, for example. In many species, as in the sunflower itself, two kinds of florets occur, known respectively as marginal or ray-florets, and central or disc-florets, the ray florets forming a floral display, the disc-florets being inconspicuous in this respect. In such cases the marginal or ray-florets are generally sterile or not seed-bearing, and the disc-florets fertile or seed-bearing. In the dandelion there is no distinction between ray-florets and disc-florets, either in appearance or function, all of the florets of the head being equally fertile. The dandelion is among the few seed plants which set seed without fertilization. The organs of fertilization (stamens and pistils) are present, and pollen is regularly produced, but seeds are formed without fertilization. If we cover the heads of dandelions with waxed paper sacks to prevent the approach of insects, and cut off the stigmas, or receptive portion of the pistils when they open, seeds will set as uniformly as though the heads were left open and exposed, and the stigmas undisturbed. Pollination, necessary for seed-production in most plants, is not so here. This fact, of course, ensures a constant crop of seed independently of favourable conditions for pollination.

The Dandelion Plant

The dandelion is a long-lived perennial with a widely-branched root system, surmounted by a "crown" which divides, forming numerous crown-branches, the amount of branching of the crown depending upon the degree of crowding and the age of the plant. In an uncrowded area, chosen for investigation in recently cultivated soil, with plenty of room available for maximum development, data for size of plants were found as shown in Table 1.

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TABLE 1

Plant No.	Age of plant* (yrs.)	No. of crown branches	No. of principal roots	Weight of tops (oz.)	Weight of roots (oz.)
1	11	18	6	35.8	9.2
2	10	6	6	28.7	14.3
3	9	12	5	38.1	20.2
4	11	21	5	25.9	15.4
5	11	22	5	37.9	14.3
6	12	12	8	20.3	10.9
7	10	20	8	17.7	13.9
8	13	11	7	19.5	14.3
9	10	16	5	26.6	10.4
10	8	11	9	42.2	14.0

* Determined by counting the number of annual rings in the root, as in the case of tree stems.

In thickly infested areas, densely crowded with dandelions, the number of crown-branches, and consequently of seed-bearing heads is naturally less.

Reproduction

In order to obtain data for the rate of reproduction of the dandelion, a blue-grass field was selected which was practically solidly occupied by dandelions throughout, the blue-grass being totally invisible during the flowering and seeding of the dandelions. To the eye, the entire field during

TABLE 2.—DANDELION FIELD COUNTS

Circle No.	No. of plants	No. of seed-bearing heads in circle	Circle No.	No. plants	No. of seed-bearing heads in circle
1	126	254	26	10	40
2	118	238	27	126	382
3	106	202	28	111	230
4	80	155	29	137	250
5	86	154	30	104	178
6	116	197	31	94	150
7	103	192	32	30	79
8	95	187	33	290	425
9	106	202	34	45	110
10	112	221	35	104	198
11	126	248	36	173	345
12	92	173	37	196	431
13	111	183	38	121	230
14	97	140	39	90	147
15	110	170	40	23	90
16	94	143	41	48	138
17	123	267	42	50	148
18	98	171	43	167	348
19	38	121	44	73	203
20	46	136	45	89	194
21	148	297	46	153	264
22	96	163	47	173	307
23	18	62	48	165	273
24	100	191	49	140	200
25	137	296	50	82	163
				5,276	10,187

this time, with the exception of small isolated areas, was a solid mass of dandelion plants. Estimates were made of the number of plants and the number of seed-bearing heads per square yard, by counts made of the number of each, within the area of a circular hoop (1,008 sq. inches, or approx mately $\frac{3}{4}$ of a square yard—exactly 0.77 square yard), thrown at random over the field, zig-zag, in two principal directions—east and west, and north and south—transecting the field. Fifty such throws were made, covering a total of 350 square feet, and representative of the entire field.

Counts were made in each of the 50 circ e areas, of the number of dandelion plants, and the number of seed-bearing heads, no distinction being made in this series of counts between young plants and seed-bearing plants, the object being primarily to determine the present average amount of seed-production per square yard of the field. The data are given in Table 2.

Converting the data to a basis of numbers per square yard, we have the results shown in Table 3.

TABLE 3.—SUMMARY OF DATA FROM TABLE 2

Plants

Maximum No.		Minimum No.		Average No.	
Per circle area	Per square yard	Per circle area	Per square yard	Per circle area	per square yard
290	377	10	13	105.5	137
Seed-bearing Heads					
425	552	40	52	204	265

Total Number of plants in area (350 sq. ft.)...............	5,276
Total number of seed-bearing heads........................	10,187
Average number of plants per square yard..................	137
Average number of seed-bearing heads per square yard.......	265

Reducing the data in preceding Table 3 to a basis of square yards, and classifying them according to the number of plants and number of heads per square yard, we have the results shown in Table 4.

Thus, in the case of a densely infested field, the greatest tendency (about 37% of the total number of counts, Table 4), will be to have 101-150 plants per square yard, and 151-200 heads per square yard, (31% of the total number of counts, Table 4.)

In the 50 field counts referred to, no attempt was

TABLE 4.—PLANTS AND HEADS PER SQUARE YARD

No. of plants per square yard	No. of cases	Per cent no. of cases in each class
1 - 50	10	17
51 - 100	18	30
101 - 150	22	37
151 - 200	9	15
201 - 250	0	0
251 - 300	1	2
	60	101

TABLE 4—*Conc.*

No. of heads per square yard	No. of cases	Per cent no. of cases in each class
1 - 50	1	2
51 - 100	3	5
101 - 150	12	21
151 - 200	18	31
201 - 250	9	16
251 - 300	9	16
301 - 350	3	5
351 - 400	0	0
401 - 500	3	5
	58	101

made to determine the *number of seed bearing heads per plant,* the total number of plants and the total number of seed-bearing heads per circle-area being taken independently, the object being to ascertain the extent of occupancy of the ground by the dandelion plants, and the total rate of seed production from the area in question. To assist in determining the latter, counts were made of the number of seeds in each of 100 heads, taken at random from the field under observation. The data are given in Table 5.

TABLE 5.—SEED PRODUCTION PER HEAD

Head No.	No. of seeds per head	Head No.	No. of seeds per head	Head No.	No. of seeds per head
1	246	34	208	67	235
2	194	35	196	68	167
3	220	36	116	69	210
4	275	37	140	70	228
5	163	38	181	71	185
6	188	39	160	72	239
7	178	40	189	73	161
8	143	41	197	74	247
9	167	42	178	75	188
10	210	43	160	76	263
11	235	44	183	77	241
12	247	45	128	78	160
13	181	46	198	79	143
14	207	47	140	80	163
15	133	48	161	81	189
16	188	49	147	82	193
17	139	50	141	83	273
18	173	51	167	84	213
19	218	52	178	85	240
20	183	53	143	86	261
21	233	54	210	87	174
22	263	55	273	88	144
23	179	56	191	89	153
24	281	57	178	90	198
25	183	58	127	91	181
26	171	59	163	92	147
27	278	60	176	93	236
28	162	61	207	94	217
29	304	62	261	95	187
30	108	63	193	96	192
31	152	64	173	97	243
32	151	65	169	98	176
33	173	66	171	99	226
				100	213
					19,215

Maximum number of seeds per head	304
Minimum number of seeds per head	108
Average number of seeds per head	192

From Table 5, we have an average of 192 seeds per head for the area in question, an area, as stated, densely populated with dandelions. The average number of seed-bearing heads per square yard for the same area being found to be 265 (Table 3), the total average number of seeds produced *per square yard* in this heavily infested area would be 50,880.

TABLE 6.—HEADS PRODUCED PER SEED-BEARING PLANT

Circle area	No. of seed-bearing plants	No. of heads	No. of heads per plant
1	97	243	2.5
2	61	138	2.3
3	85	173	2.4
4	102	381	3.7
5	62	103	1.7
6	91	238	2.6
7	93	208	2.2
8	77	168	2.2
9	106	361	3.4
10	89	346	3.9
11	73	126	1.7
	936	2,485	28.6
Average	85	226	2.6

Average number of plants per square yard 110
Average number of heads per square yard 294

In order to ascertain the average number of heads produced *per seed-bearing plant*, a count was made of the number of seed-bearing plants within eleven circle-areas, taken as before, and in the same field, but in one of the most densely occupied areas of that field. The data are shown in Table 6.

From these data we get the following:—

Average number of seed-bearing plants per square yard	110
Average number of seed-bearing heads per square yard	294
Average number of seeds borne per square yard, at 192 seeds per head, (Table 5)	56,448

The first series of 100 counts (Table 5), giving 50,880 seeds produced per square yard, were made as stated, to cover an average of the entire field; the second count was made in one of the most densely occupied portions of that field. The summary of the two series of counts is then as follows:

	No. of seeds produced per square yard
1.—(100 circle areas, Table 5)	50,880
2.—(11 circle areas, Table 6)	56,448

This would give a possibility of from 246,259,200 to 273,208,320 seeds produced per acre from similarly infested land. In other words, in round numbers, a badly infested field will be likely to produce and distribute from fifty to fifty-six thousand seeds per square yard, or from 240 to 270 million seeds per acre of infested ground.

This however, is not the maximum rate of seed-production by the dandelion. Counts were also made of the number of seeds per head, in the case of 100 heads gathered from the edge of a shelter-belt of trees and shrubs bordering on cultivated ground, and but a short distance from the field formerly examined. Here, the dandelions were not in turf and were growing with full room for maximum development.

As in the preceding area (see foot of Table 5), the data may be summarized as follows:—

Maximum number of seeds per head	412
Minimum number of seeds per head	130
Average number of seeds per head	252

Comparing the rate of seed production per head, in the two areas referred to we have:—

—	No. of seeds per head		
	Maximum	Minimum	Average
Badly infested field	304	108	192
Shelter-belt margin, bordering cultivated field	412	130	252
Difference	36%	20%	31%

We thus see how a shelter-belt margin for example, forming a trap for the floating dandelion seeds, may constitute a breeding-place for the reproduction of the dandelion, and at a far greater maximum and minimum rate (36% and 20% respectively), than in the field from which the seed was borne.

Another factor in the re-infecting of lawns, is the fact that in shelter-belt margins, unoccupied ground areas, etc., not only is the number of *seeds per head greater*, as has been shown, but likewise the number of *heads per plant increases*. In the field forming the subject of the principal examination, the average number of heads per seed-bearing plant was found to be 2.6. However, in the area of unoccupied ground, lying to the east of the shelter-belt in question, the number of heads per plant is much greater. Fifteen plants taken at random in this area averaged 93 heads per plant.

Hence, in scattered breeding areas of this description, the production of heads for the plants occupying the ground, may be *thirty-six times* as much as in the infested lawns or fields themselves, to which fact is to be added an increase of *seed-production per head* of from 20% to 36%. Hence the necessity, not only for ridding private lawns, public parks, golf courses etc., of dandelions, but of eradicating them so far as possible, from the adjacent spots which serve as breeding-places.

PROPAGATION OF THE DANDELION FROM LAWN CUTTINGS

On June 7th, a quantity of lawn cuttings was brought in from a lawn badly infested with dandelions, and which had been cut by the lawn mower while the dandelions were in full bloom. The sweepings when gathered, had dried in the sun, and the partially ripening flower-heads had formed the type of "fluff" (mass of half-ripened seeds with seed-hairs) characteristic of dandelion cuttings. The total weight of these dried seed-heads was 128.9 grams ($4\frac{1}{2}$ oz.). The weight of seeds taken from this mass amounted to 8.35 grams ($\frac{1}{3}$ oz.).

On June 8th, random samples of dandelion seeds, both green and ripe in appearance, from the lawn-sweepings or dandelion "fluff" referred to, were put in germinators in the laboratory, and removed from the germinators on June 27th. The results as to germination are given in Table 7.

TABLE 7.—GERMINATION OF DANDELION SEEDS FROM LAWN SWEEPINGS. DANDELIONS CUT WHILE IN FULL BLOOM; FLOWER-HEADS PARTIALLY RIPENING IN THE SUN UPON THE GROUND

Germination no.	Total no. of seeds	No. of seeds germinated	No. of seeds ungerminated	Per cent of seeds germinated
1	300	49	251	16.3
2	300	23	277	7.6
3	300	20	280	6.6
4	300	45	255	15.0
5	300	66	234	22.0
6	300	24	276	8.0
	1,800	227	1573	Av. 12.6

From these results it appears that on the average about 13% of the seeds ripening or partially ripening in dandelion heads cut by the lawn mower when in full bloom, and left on the lawn, may germinate if they are washed down into the soil of the lawn. It appears therefore advisable, in a dandelion-infested lawn, to use where practicable a lawn mower attachment for catching the sweepings as cut, so that they can be removed from the ground.

SUMMARY

1. The dandelion is one of the few seed plants which produce seed without fertilization. This is one of the essential factors in the success of the dandelion as a weed.

2. The dandelion is a perennial plant, capable of living for a number of years. Plants 10–13 years old are readily found (age determined by counting the annual growth-rings in the principal roots).

3. In areas where the dandelion plants are not crowded, and hence have sufficient room for individual growth, as along ploughed field margins, along shelter-belts, etc., as many as from 11 to 22 crown branches may develop from a single plant. Counts from fifteen such plants, gave from 48 to 146 heads per plant, with an average of 93; counts of the number of seeds per head in one hundred heads of such plants, gave 130 to 412 seeds per head, the average being 252. This gives an average possibility of 23,436 seeds which may be produced *per plant* growing under what may be called nearly maximum conditions, when in full bloom. Head production in such breeding areas may be thirty-six times as much as in the infested lawns adjoining, and seed-production of such heads is 20–36% greater. Since these seeds are all readily transportable by the wind, by means of the white parachute of spreading hairs called the "pappus", which grows from the top of the dandelion seed, the sowing of the neighbouring areas from such border growths of dandelions is readily effected.

4. In heavily infested lawns, the number of dandelion plants, as estimated from 50 counts made at random on such an area, was found to range from 13 to 377 per square yard, the average number being 137. The number of seed-bearing heads from the same area ranged from 52 to 552 per square yard,—the average being 265. In the same area the number of seeds per head ranged from 108 to 304, the average being 192. The total average number of seeds which may be produced upon such an infested area would thus amount to 50,880 per square yard, or 246,259,200 per acre.

5. The average number of seed-bearing heads per plant, in a heavily infested area such as the one reported upon, was also further determined by making counts within eleven circle-areas, taken as before from the same field, but from *one of the most heavily infested* areas of that field. The number of seed-bearing plants per square yard ranged from 79 to 138, the average being 110. In this area the average number of seed-bearing heads per plant was found to be 2.6. The number of seed-bearing heads per square yard ranged from 134 to 495, the average being 294. At the rate of 192 seeds per head as ascertained for the above field in general, the total average number of seeds produced per square yard in the highly infested area just referred to, would be 56,448, or 273,208,320 per acre.

6. When dandelions are cut by the lawn-mower while in full bloom, the seeds from the dried heads which have ripened after cutting, may germinate to about 13% of the total number of seeds. It is advisable, therefore, to catch all cuttings from a dandelion-infested lawn in a lawn-mower attachment, so that they can be removed and destroyed.

THE INHERITANCE AND USE OF PHENOL COLOUR REACTION IN HARD RED SPRING WHEATS[1]

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In a previous paper, the authors (1) presented the results of their investigations on the colour reaction of certain Canadian hard red spring wheats when treated with a 1% phenol solution. It was suggested in that article that the phenol reaction possibly might be related closely to the maturity of the wheat kernels and heads employed, and further that this colour reaction might be used to advantage in determining the segregation that takes place in certain wheat crosses. Voss (2) found that some varieties differed in the colour reaction in the case of floral parts. The following article presents in two parts the results of experiments conducted at Ottawa in an effort to obtain information on these points. Part I deals with the phenol reaction of certain wheats at various stages of maturity while Part II[4] prepared entirely by the junior author deals with the inheritance studies made on the two prominent hard red spring wheats Red Fife and Garnet.

PART I.—MATERIAL AND METHODS

It was thought advisable to determine the phenol reaction of a few of the well known and highly stable varieties of wheat found in general use in Canada and the following varieties were, therefore, investigated:

Canus	C.A.N. 1260
Garnet Ott. 652	C.A.N. 1316
Marquis Ott. 15 E. 32	C.A.N. 1831
Red Fife Ott. 17	C.A.N. 1515
Reward Ott. 928	C.A.N. 1509
Reward 22–42	C.A.N. 1715
Ruby Ott. 623	C.A.N. 1511

Other varieties have been investigated but, for the sake of brevity, results on the above varieties provide ample information and will suffice.

To provide material which would be as uniform as possible from th point of maturity 400 heads, all emerging from their sheaths the same day, were marked. Then from the soft dough stage until four days after the heads were ripe, at two-day intervals, 20 heads were cut, the kernels removed by hand at once and the green weight determined. Four grams of the freshly removed kernels were at once placed in envelopes and the dry weight determined. The heads and remaining kernels were carefully stored in envelopes until the colour reactions could be studied.

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[4] Part of a thesis submitted to the Faculty of Graduate Studies and Research of McGill University in partial fulfilment of the requirements for the degree of Master of Science, granted in May, 1936.

TABLE 1.—COLOUR REACTIONS FOR VARIOUS VARIETIES OF WHEAT *(see footnote for legend)*

Variety	Date cut	Stage of maturity	Per cent dry wt. (gms.)	Phenol Reaction					
				Kernels		Floral Parts			
				Before treatment	After treatment	Outer glume	Lemma	Awns	Palea
Canus	26 July	Soft Dough	45.86	Green	I+	III	II	II	II
	28 July	Soft Dough	47.62	Few turning	II Misc.				
	30 July	Soft Dough	49.42	Few green	III Misc.	IV	II	IV	III
	1 Aug.	Late Dough	57.22	Turned	III Uniform	III	II	II	II
	3 Aug.	Late Dough	58.00	Very few green	II+ Uniform	IV	III	III	III
	5 Aug.	Late Dough	62.82	Ripe	III Misc.	IV	III	III	IV
	7 Aug.	Hard Dough	70.82	Ripe	III Uniform	III	II	III	III
	9 Aug.	Hard Dough	80.62	Ripe	III+	III−	II	IV−	III
	11 Aug.	Hard Dough	85.50	Ripe	III+	III−	II	II	III
	13 Aug.	Ripe	86.75	Ripe	III+	III	II	III	III
	15 Aug.	Ripe	88.25		III+	III	III	III	III
	17 Aug.	Ripe	88.92		III+	III	III	III	III
Garnet	24 July	Soft Dough	56.13	Green	I	I	I	I+	I
	26 July	Soft Dough	57.77	Half ripe	I+	I	I	I+	I
	28 July	Late dough	61.75	Ripe	–	–	–	–	–
	30 July	Hard dough	70.27	Ripe	II+	I	I	I−	I
	1 Aug	Ripe	78.42	Ripe	II+	I	I	I	I
	3 Aug.	Ripe	85.82	Ripe	III+	I	I	I−	I
	5 Aug.	Ripe	81.48	Ripe	IV	I	I	I−	I
Marquis Ott. 15 (E. 32)	28 July	Soft dough	47.82	Green	I+	II	II	II	I
	30 July	Soft dough	43.92	Half ripe	I+ Misc.	II	II	II	I
	1 Aug.	Soft dough	56.70	Nearly ripe	II+	III	III	III	III
	3 Aug.	Soft dough	52.42	Nearly ripe	II+	III	III	III	III
	5 Aug.	Soft dough	54.42	Nearly ripe	III−	IV	III	III	III
	7 Aug.	Late dough	58.12	Nearly ripe	III−	IV	III	III	III
	9 Aug.	Hard dough	75.50	Ripe	III	IV	IV	IV	III
	11 Aug.	Ripe	79.08	Ripe	III	IV	IV	IV	III
	13 Aug.	Ripe	85.75	Ripe	III+	IV	IV	IV	III
	15 Aug.	Ripe	85.70	Ripe	III+	IV	IV	IV	IV
	17 Aug.	Ripe	86.22	Ripe	III+	IV	IV	IV	IV
	19 Aug.	Ripe	86.80	Ripe	III+	IV	IV	IV	IV

Red Fife Ott. 17	28 July	Soft dough	37.18	Red	I	II	II	II	I
	30 July	Soft dough	44.50	Red, few green	I	II	II	II	I
	1 Aug.	Soft dough	53.48	Ripe	II−	III+	III	III	II
	3 Aug.	Soft dough	49.90	Ripe	II− Misc.	III+	III	III	II
	5 Aug.	Soft dough	51.42	Ripe	II−	III+	III	III	II
	7 Aug.	Soft dough	56.44	Ripe	II−	III	III	III	II
	9 Aug.	Late dough	71.20	Ripe	II−	III+	III	III	III
	11 Aug.	Late dough	70.20	Ripe	II+	III+	III	III	III
	13 Aug.	Ripe	81.18	Ripe	II−	III+	III	III	III
	15 Aug.	Ripe	84.92	Ripe	II−	III+	III	III	III
	17 Aug.	Ripe	85.78	Ripe	II	III+	III	III	III
	19 Aug.	Ripe	85.98		II	III+	III	III	III
Reward Ott. 928	24 July	Soft dough	52.98	Greenish	I	III	III	III	III
	26 July	Soft dough	48.00	Red	I+	III	III	III	III
	28 July	Soft dough	55.44	Red (seed lost)	–	–	–	–	–
	30 July	Late dough	57.55	Red (seed lost)	–	–	–	–	–
	1 Aug.	Hard dough	74.92	Ripe	III−	IV	IV	IV	IV
	3 Aug.	Hard	80.78	Ripe	III	IV	IV	IV	IV
	5 Aug.	Ripe	84.20	Ripe	III	IV	IV	IV	IV
Reward 22–42	24 July	Soft dough	51.36	Green	I Green	II−	II−	II	II
	26 July	Soft dough	51.60	Half green	I+	II−	II−	II	II
	28 July	Soft dough	57.65	Turning	II− Few green	III−	III−	III−	III
	30 July	Late dough	59.30	Ripe	III Few green	III	III	III	III
	1 Aug.	Hard dough	68.85	Ripe	III Misc.	III	III	III	III
	3 Aug.	Hard dough	84.78	Ripe	III Misc.	III	III	III	III
	5 Aug.	Ripe	84.72	Ripe	III Misc.	III	III	III	III
Ruby Ott. 623	1 Aug.	Hard dough	75.05	Ripe	I+	III	III	III	III
	3 Aug.	Hard dough	57.98*	Ripe	I+	III	III	III	III
	5 Aug.	Hard dough	79.95	Ripe	I+	III	III	III	III
	7 Aug	Hard dough	81.70	Ripe	I+	III	III+	III	III+
	9 Aug.	Ripe	87.75	Ripe	I+	III	III+	III	III
	11 Aug.	Ripe	86.42	Ripe	I+	III	III+	III	III

I—Colourless. II—Pale brown. III—Brown—often difficult to distinguish. IV—Dark brown—often difficult to distinguish. V—Black. Misc.—Where some kernels are ripe and others less mature.

*Taken after rain.

The kernels were first soaked in water for sixteen hours, drained and let dry for one hour, then immersed in 5 c.c. of 1% phenol solution for four hours and then dried on blotting paper. The colour was observed and recorded after four hours and again in two days. The head, outer glumes, lemma, awns and palea were treated for twenty-four hours in a 1% phenol solution, removed and dried.

In the following tables are given the typical colour reactions observed after the different varieties were removed and dried.

Table 1 shows that the phenol reaction becomes intensified with the maturity of the plant and with the increase in dry matter content. It is obvious, therefore, that in making use of this phenol reaction, the material treated must be mature and must have a dry matter content of at least 80%. In some cases, it will be noticed that the dry matter content is lower than on the preceding date due to the fact that the heads were taken immediately after a rain and, therefore, contained relatively more moisture.

PART II.—MATERIAL AND METHODS

Thus far, no adequate genetical evidence has been given on the nature of the phenol colour inheritance. It was found that the Garnet variety of wheat produces a colourless spike and dark brown kernels upon treatment with a solution of phenol, while Red Fife spike and kernel coloured dark brown and pale brown, respectively. The parents, F_1, F_2 and F_3 were grown in the field during the summer of 1935, and after harvest were subjected to the phenol treatment in the same manner as outlined in Part I. The following tables show the results.

TABLE 2.—F_2 FAMILIES AND THE NUMBER OF PLANTS PRODUCING THE PARENT RANGE OF PHENOL COLOUR REACTIONS OF SPIKES AND KERNELS

Population numbers	Number of spikes and kernels in phenol colour classes			
	Dark brown		Pale brown and colourless	
34 – 44 A	42	*(48)	15	(9)
34 – 44 B	36	(39)	18	(15)
34 – 45	64	(65)	22	(21)
34 – 54 B	32	(34)	13	(11)
Total	174	(186)	68	(56)

TABLE 3.—GOODNESS OF FIT OF KERNEL OBSERVATIONS IN TABLE 2

	Observed	Calculated	(O–C)	$(O-C)^2$	$\frac{(O-C)^2}{C}$
Dark Brown	174	181.5 (3)	7.5	56.25	.3099
Pale brown	68	60.5 (1)	7.5	56.25	.9297
Total	242	242.0			X^2 = 1.2396 P = .20 to .30

*Numbers in brackets refer to the spikes.

TABLE 4.—GOODNESS OF FIT OF SPIKE OBSERVATIONS IN TABLE 3

	Observed	Calculated	(O–C)	$(O-C)^2$	$\frac{(O-C)^2}{C}$
Dark brown	186	181.5 (3)	4.5	20.25	.1115
Colourless	56	60.5 (1)	4.5	20.25	.3345
Total	242	242.0			X^2 = .4462 P = .30 to .50

TABLE 5.—F_2 PHENOL COLOUR REACTION OF SPIKES AND KERNELS ON THE SAME PLANT

Population numbers	Number of plants in colour classes		
	Garnet colour	Garnet kernel colour Red Fife spike colour	Red Fife colour
34 – 44 A	9	33	15
34 – 44 B	15	23	16
34 – 45	21	44	21
34 – 54 B	11	22	12
Total	56	122	64

TABLE 6.—GOODNESS OF FIT OF DATA PRESENTED IN TABLE 5

	Observed	Calculated	(O–C)	$(O-C)^2$	$\frac{(O-C)^2}{C}$
Garnet colour	56	60.5 (1)	4.5	20.25	.3345
Segregating	122	121.0 (1)	1.0	1.00	.0081
Red Fife colour	64	60.5 (1)	3.5	12.25	.2024
Total	242	242.0			X^2 = .5452 P = .70 to .80

Tables 2 to 4 inclusive indicate that kernel and spike phenol colour reaction are each due to a single gene; combined one would expect a 9 : 3 : 3 : 1 ratio. From the data in Tables 5 and 6 in which Garnet and Red Fife phenol colour reaction of both kernels and spike are taken together, it is seen that a 1 : 2 : 1 ratio is obtained. There are two possible explanations.

1. An allelomorphic factor hypothesis. If this were the case Garnet and Red Fife would have different allelomorphs controlling phenol colour reaction of spikes and kernels. The genotypes would be as follows:

Garnet CC $\times$ Red Fife C_1C_1
F_1 CC_1
F_2 1 CC : 2 CC_1 : 1 C_1C_1

Where C results in coloured kernel and colourless spike and C_1 in pale coloured kernel and coloured spike.

2. The complete linkage of two factors: if this were the case the genotypes would be as follows:

Garnet colourless spike (p_sp_s), dark brown kernels (P_kP_k)
Red Fife dark brown spike (P_sP_s), pale brown kernels (p_kp_k)
F_1 Dark brown spike and kernels $\overline{p_sP_k}\ \overline{P_sp_k}$
F_2 $1\ \overline{p_sP_k}\ \overline{p_sP_k} : 2\ \overline{p_sP_k}\ \overline{p_sP_k} : 1\ \overline{P_sp_k}\ \overline{P_sp_k}$

If the dihybrid hypothesis were correct, one would expect a double recessive combination once out of every 16 F_2 plants. Since this did not occur in the F_2 or F_3, they must be completely linked. From the developmental genetic standpoint it is more reasonable to assume that two factors were involved, since the Garnet parent gave a colourless spike and brown kernel reactions, and Red Fife dark spike and pale kernel reactions.

It will be noted that in spite of the fact that Red Fife appears in the parentage of all the varieties studied, practically all of the latter differ from Red Fife in respect of kernel colour reaction to phenol treatment. It is evident, therefore, that the quality found in Red Fife wheat is passed on in part at least, irrespective of the phenol colour reaction of this variety. Similarly, it would appear that the production of new varieties which may be distinguished on the basis of colour reaction can hardly be expected owing to the occurrence of complete linkage.

SUMMARY

1. Spring wheat varieties Canus, Garnet, Marquis, Red Fife, Reward and Ruby harvested at two day intervals from the soft dough to maturity were treated with a 1% phenol solution, and gave intensified reactions as they approached maturity and increased in dry matter content.

2. The kernels, spikes and floral parts were all influenced by the maturity of the plants.

3. The colour reactions at maturity were as follows:—

	Kernels	Floral Parts
Canus	Brown	Brown
Garnet Ott. 652	Dark brown	Colourless
Marquis Ott. 15 E. 32	Dark brown	Dark brown
Red Fife Ott. 17	Pale brown	Brown
Reward Ott. 928	Dark brown	Dark brown
Reward 22–42	Dark brown	Brown
Ruby Ott. 623	Pale brown	Brown

4. There are two possible explanations of the inheritance of phenol colour reactions of spike and kernel in a cross of Garnet and Red Fife wheat; namely, allelomorphic factors, or two completely linked factors. The latter seems more plausible from the developmental standpoint.

ACKNOWLEDGMENT

The authors wish to acknowledge the assistance given by the Chemistry Division, C.E.F. for the moisture determination, and to Dr. R. M. Love for helpful suggestions in connection with the genetical analysis of the data.

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Résumé

La transmission héréditaire et l'emploi des réactions de couleur chez le blés rouges durs de printemps traités au phénol. J. G. C. Fraser et F. Gfeller, Ferme expérimentale centrale, Ottawa, Ont.

Les variétés de blé de printemps Canus, Garnet, Marquis, Fife Rouge, Reward et Ruby, récoltées à deux jours d'intervalle, à partir de la phase du grain mou jusqu'à la maturation, et traitées avec une solution de phénol à 1%, ont eu des réactions de plus en plus forte à mesure que la maturité s'avançait et que la proportion de matière sèche augmentait. Les grains, les épis et les parties florales ont tous été influencés par la maturité des plantes. Les réactions de couleur à maturité étaient les suivantes:—

	Grains	Parties florales
Canus	Brun	Brun
Garnet Ott. 652	Brun foncé	Incolores
Marquis Ott. 15E. 32	Brun foncé	Brun foncé
Fife Rouge Ott. 17	Brun pâle	Brun
Reward Ott. 928	Brun foncé	Brun foncé
Reward 22-42	Brun foncé	Brun
Ruby Ott. 623	Brun pâle	Brun

Il y a deux explications possibles dans cette transmission hériditaire des réactions de couleur des épis et des grains traités au phénol dans un croisement de Garnet et de Fife Rouge, savoir: les facteur allélomorphiques, ou deux facteurs complètement reliés. Cette dernière explication paraît être la plus plausible au point de vue du développement.

EFFECT OF FERTILIZERS ON YIELD AND MALTING QUALITY OF MANITOBA BARLEY[1]

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Some experiments on the fertilizing of barley were undertaken at the Manitoba Agricultural College in 1926 and 1927 by Professor T. J. Harrison. The object of this paper is to describe the results of these experiments, which have been examined statistically by the author.

OUTLINE OF INVESTIGATION

Three sets of experimental results were accumulated, viz.:

1926. O.A.C. 21 barley grown on plots summerfallowed in 1925 and fertilized in 1926.

1927. A second crop of O.A.C. 21 barley grown on the foregoing plots in order to test residual effects of the fertilizers.

1927. O.A.C. 21 barley grown on plots summerfallowed in 1926 and fertilized in 1927.

Six fertilizers, namely phosphate, potash, nitrate, ammonium sulphate, cyanamide and sulphur were studied in 1926, and five in 1927, when sulphur was omitted. They were applied as broadcast top dressings at the following heavy rates:

1111 lb. Triple acid phosphate per acre
444 lb. Potassium chloride per acre
666 lb. Sodium nitrate per acre
888 lb. Ammonium sulphate per acre
1111 lb. Cyanamide per acre
1111 lb. Sulphur per acre

The experimental plots were laid out in the field in a series of Latin Squares, one square being devoted to the study of each fertilizer. Each square contained 16 plots, of which four were unfertilized, four were treated with a single fertilizer at the time of seeding, four were treated with a single fertilizer at the time of heading, and four received a "complete" fertilizer supplying nitrogen, phosphate and potash (also sulphur in the sulphur square) at the time of seeding.

Observations recorded included the number of days from seeding to maturity, percentage lodging (as estimated visually), length of straw, yield of straw and of grain, and the weight per bushel, weight per 1000 kernels, volume per 1000 kernels, protein content, ash content and coefficient of mealiness of the grain of each plot. Chemical and physical determinations were made by the methods outlined by Harrison (4).

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[1] Contribution from the Division of Biology and Agriculture, National Research Laboratories, Ottawa. Published as Paper No. 105 of the Associate Committee on Grain Research of the National Research Council and the Dominion Department of Agriculture.

[2] Biologist, National Research Laboratories.

TABLE I.—METEOROLOGICAL DATA

Period	Precipitation as inches of rain		Temperature, deg. F.					
			Av. daily mean		Av. daily max.		Av. daily min.	
	1926	1927	1926	1927	1926	1927	1926	1927
Aug. 1, preceding year to Apr. 30, crop year, inclusive	9.36	15.67	–	–	–	–	–	–
May	0.83	4.70	58.0	49.0	70.0	56.3	45.0	40.9
June	3.53	1.79	59.0	61.0	68.5	71.6	49.1	51.2
July	2.01	1.14	68.0	66.0	80.1	76.7	55.8	54.3
August	3.23	2.85	64.0	63.0	75.1	74.7	53.5	51.9

As shown in Table I, both rainfall and temperature conditions differed considerably in the season of 1926 and 1927. Disparities in the response to fertilizers in the two years no doubt arose in part from this circumstance, although soil differences may also have been a contributory factor.

RESULTS

The results obtained in the three experiments were examined statistically, the significance of treatment effects in each square being determined by an analysis of variance (3). Necessary differences, for a 5% level of significance, between individual treatment means were also computed from the residual variation of replicate plots, after the elimination of average differences between rows and columns of the squares, which affect all comparisons of treatments equally (3).

The fertilizers had some effect on the number of days required by the crop to reach maturity, but this was not the same in the two seasons. In 1926 the summerfallowed plots receiving phosphate at seeding ripened three days earlier than those unfertilized. Potash retarded maturity by three days in the plots fertilized at the time of seeding and by two days in those fertilized at heading. The various forms of nitrogen when applied at seeding either alone or in combination with phosphate and potash caused a retardation of five days. These effects were not reproduced in the 1927 summerfallowed plots, which showed no significant differences in date of maturity, but it was observed that the second crop of barley grown in 1927 on stubble ripened from one to four days earlier in the plots receiving the combined fertilizers (nitrogen, phosphate and potash) in 1926 than in the unmanured plots of the same square.

Significantly increased yields of straw were obtained in the 1926 experiment from the applications at seeding of phosphate alone, phosphate with nitrate and potash, and phosphate with cyanamide and potash. Cyanamide alone at seeding significantly increased straw production, and at heading significantly diminished it. The application of cyanamide at heading seems however to have been such as to produce herbicidal rather than manurial effects, since it affected all characteristics of the crop adversely. The results obtained from the addition of sulphate of ammonia at heading in 1927 are also open to suspicion on the same score.

Repetition of the fertilizer trial in 1927 gave results differing in some respects from those obtained in 1926. Phosphate alone at seeding or heading increased the weight of straw produced, but in combination gave irregular results, including a significantly depressing effect when applied together with cyanamide and potash at seeding. The application of cyanamide at heading, which produced anomalous results in 1926, was unfortunately omitted in 1927.

Significant residual effects on straw production were confined to the nitrogenous fertilizers, particularly cyanamide and ammonium sulphate. The plots receiving nitrate alone, either at seeding or at heading, in 1926, failed to show any significant increase over the unfertilized in 1927.

Apparently these increases or decreases in straw yield were largely the outcome of stimulation or repression of tillering by the fertilizers, for the average length of straw was on the whole but little affected. Furthermore, such differences in length as were demonstrable were not always in conformity with the differences in weight. In this connection, it may be noted that the Australian experiments of Richardson and Gurney (6) revealed progressive increases in both the number of tillers and yield of straw of barley, grown on stubble land, with increased dressings of sulphate of ammonia.

In the present experiments, there were only two significant effects on straw length in the season of application of the fertilizers; in 1926 the straw of the plants receiving sulphate of ammonia, phosphate and potash at seeding was on the average $1\frac{3}{4}$ inches longer than that of the controls, and in 1927 the previously noted injurious effect of sulphate of ammonia at heading manifested itself in a reduction of straw length by 3 inches. Several residual effects of the nitrogenous fertilizers on the stubble crop were detectable, however. Nitrate in combination with phosphate and potash, and sulphate of ammonia either alone or in combination, at seeding, and all the cyanamide treatments of the previous season, resulted in increases in length of straw ranging from $3\frac{1}{4}$ inches (nitrate) to 8 inches (cyanamide with phosphate and potash).

From the practical point of view, the outstanding result of the experiments was the high percentage of lodging in the summerfallowed plots supplied with any form of nitrogen at seeding. This effect was particularly noticeable in 1926, when the unfertilized and non-nitrogenously fertilized plants stood up well. In the plots receiving nitrogen alone at seeding there was from 40 to 60% of lodging and in those supplied with nitrogen together with phosphate and potash, from 80 to 90%. Lodging occurred to some extent in all the summerfallowed plots in 1927, but was again aggravated by the addition of nitrogen with phosphate and potash at seeding. There was no lodging of any of the stubble crops in 1927.

The average length and yield (lb.) of straw, and percentage of lodging in the quadruplicate plots of each treatment in each square (omitting the single sulphur square, which revealed no significant effects attributable to sulphur) is illustrated in Figure 1. In order to bring these three quantities to a common scale the individual quadruplicate averages of, for example, straw length were expressed as a percentage of the general mean straw length for all three experiments. The same procedure was followed in the case of straw yield and percentage lodging.

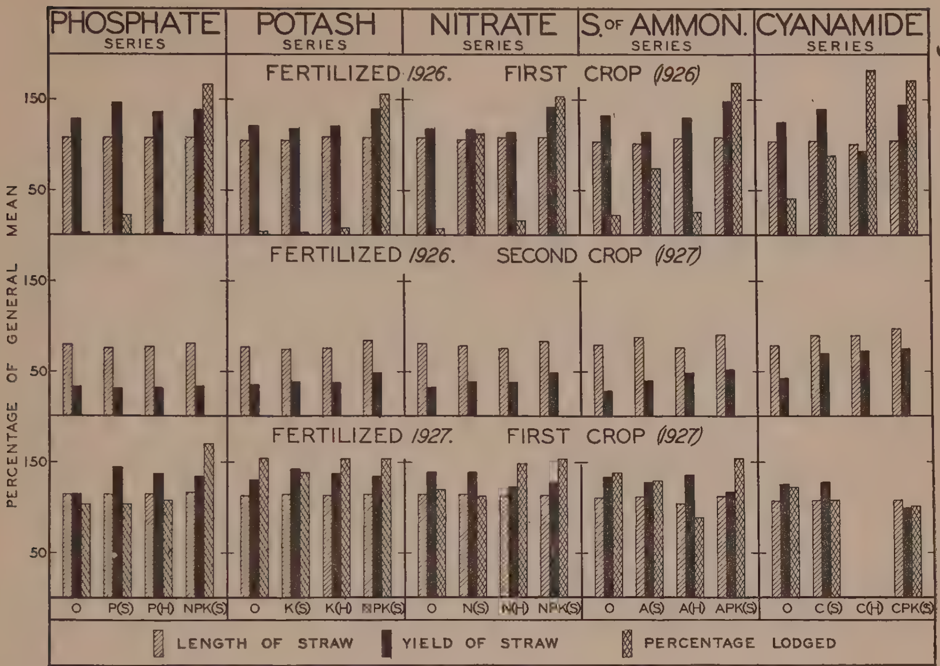

FIG. 1. *Relative effect of fertilizers on length and yield of straw and percentage of lodging. O—unfertilized. S—fertilized at seeding. H—fertilized at time of heading.*

Table 2 summarizes the effect of the fertilizers used on the yield, nitrogen content, and weight and volume per 1000 kernels of grain.

Significant increases in grain yield in the season of fertilization were confined to phosphate applied at seeding in 1926 ($5\frac{1}{2}$ bu. per acre, not reproduced in 1927) and to nitrate with phosphate and potash at seeding in 1927 ($7\frac{1}{2}$ bu. per acre, not evident in 1926). The nitrogen fertilizers had no significantly beneficial effect on yield, but caused pronounced increases in the protein content of the grain in 1926, and small increases in 1927. These differences can probably be attributed in part to the fact that moisture was more plentiful in the early part of the growing season in 1927 than in 1926. There were however pronounced residual effects of the nitrogenous fertilizers on the stubble-sown crop. These were the reverse of the direct effects, namely a pronounced increase in yield, especially from the cyanamide and sulphate of ammonia plots (as much as 25 bu. per acre over the unfertilized), without significant increase in protein content. The improvement in yield in the ammonium sulphate plots collectively (12 plots) was also quite significant, although owing to the greater variability in this square the differences between iudividual treatments (4 plots each) fell below the level required for statistical significance.

It seems to be fairly well established that in the season of application phosphate and potash together at seeding increased both the weight and volume per 1000 kernels, by about 2 gm. and 4 c.c. respectively (roughly 5%). The effects of either fertilizer applied singly were less pronounced, but these also reached the level of significance in 1927. The residual effect

TABLE 2.—EFFECT OF FERTILIZERS ON YIELD PER ACRE, PROTEIN CONTENT AND SIZE OF BARLEY GRAIN*

Series	Fertilized in 1926								Fertilized in 1927			
	First crop (1926)				Second crop (1927)				First Crop (1927)			
	Yield, bu. per acre	Protein, % (basis 13.5% moisture)	Wt. per 1000 kernels, gm.	Vol. per 1000 kernels, cc.	Yield, bu. per acre	Protein, % (basis 13.5% moisture)	Wt. per 1000 kernels, gm.	Vol. per 1000 kernels, cc.	Yield, bu. per acre	Protein, % (basis 13.5% moisture)	Wt. per 1000 kernels, gm.	Vol. per 1000 kernels, cc.
Phosphate Series												
Unfertilized	68.6	9.7	31.8	51.1	18.2	7.8	31.3	50.6	78.5	11.5	33.8	55.5
P at seeding	75.1	9.8	32.2	52.6	17.5	8.1	30.8	49.9	84.4	11.3	34.5	58.3
P at heading	63.2	10.1	32.2	52.0	17.5	7.8	30.4	48.9	78.1	10.8	35.0	58.4
NO_3, P, K, at seeding	57.6	12.9	33.3	54.6	21.6	8.9	32.2	52.0	84.3	12.4	35.9	59.1
Necessary difference	5.2	1.0	1.4	1.7	3.7	0.8	0.9	1.6	7.4	0.5	1.0	1.5
Potash Series												
Unfertilized	64.3	10.2	31.2	50.4	17.7	8.3	33.3	54.2	82.2	11.6	34.2	57.0
K at seeding	64.5	10.4	32.0	52.9	17.4	8.5	33.4	54.9	89.0	11.8	35.6	58.9
K at heading	59.6	10.6	31.8	51.8	17.8	8.1	33.2	54.0	82.4	11.6	34.0	56.6
NO_3, P, K, at seeding	65.5	13.3	33.7	55.4	24.5	7.8	34.5	56.5	85.6	12.4	36.4	59.1
Necessary difference	11.7	1.0	1.4	1.7	3.7	0.8	0.9	1.6	7.4	0.5	1.0	1.5
Nitrate Series												
Unfertilized	69.1	10.6	32.4	51.8	17.4	8.2	31.5	50.9	75.4	12.2	34.8	58.0
NO_3 at seeding	47.2	13.4	31.9	51.1	21.4	8.4	32.9	53.4	74.3	12.6	34.4	58.2
NO_3 at heading	53.5	13.9	32.7	51.5	19.5	8.7	32.3	52.8	72.7	12.3	32.9	55.4
NO_3, P, K, at seeding	67.8	13.3	33.3	54.0	24.4	8.2	32.9	53.1	82.9	12.7	35.5	58.6
Necessary difference	11.7	1.0	1.4	1.7	3.7	0.8	0.9	1.6	7.4	0.5	1.7	1.5
Sulphate of Ammonia Series												
Unfertilized	77.8	11.8	32.9	52.8	26.5	9.3	33.1	55.8	73.0	11.8	34.0	57.4
S/A at seeding	49.9	13.7	32.2	52.6	33.8	8.5	34.7	57.3	77.3	12.7	32.6	56.4
S/A at heading	74.2	12.8	33.6	54.1	42.6	8.9	34.7	58.7	73.0	11.8	32.2	55.2
S/A, P, K at seeding	60.7	14.1	35.2	58.1	41.8	9.0	35.2	58.5	79.0	12.7	35.3	59.0
Necessary difference	5.2	1.0	1.4	1.7	17.2	0.9	1.1	1.9	7.4	0.5	1.0	1.5

Cyanamide Series												
Unfertilized	68.3	12.3	33.4	53.5	26.2	9.1	34.1	56.7	74.8	12.0	34.7	58.7
Cyanamide at seeding	65.8	**14.2**	**34.9**	55.1	**48.9**	9.9	35.0	58.0	76.3	12.2	33.4	57.1
Cyanamide at heading	**25.6**	**13.4**	**25 5**	**44.9**	**49.2**	9.3	35.2	58.3	—	—	—	—
Cyanamide, P, K, at seeding	59.8	**14.0**	**35.9**	**58.2**	**50.0**	9.2	36.0	60.0	73.0	12.2	34.8	58.1
Necessary difference	11.7	1.0	1.4	1.7	19.8	0.9	2.3	4.3	7.4	0.4	1.5	3.0
Sulphur Series												
Unfertilized	63.9	11.3	33.0	52.2	—	—	—	—	—	—	—	—
S at seeding	64.8	11.0	32.4	52.4	—	—	—	—	—	—	—	—
S at heading	67.4	11.3	32.5	52.5	—	—	—	—	—	—	—	—
NO_3, S, P, K at seeding	**49.4**	**13.2**	34.1	**55.0**	—	—	—	—	—	—	—	—
Necessary difference	5.2	1.0	1.4	1.7	—	—	—	—	—	—	—	—

* Boldface type indicates significantly higher or lower than unfertilized.

of the nitrogenous fertilizers on the stubble plots was also to increase both weight and volume per 1000 kernels.

The relative treatment averages of grain yield, weight per 1000 kernels and nitrogen content are shown in Figure 2 by the same method of representation as was used in Figure 1.

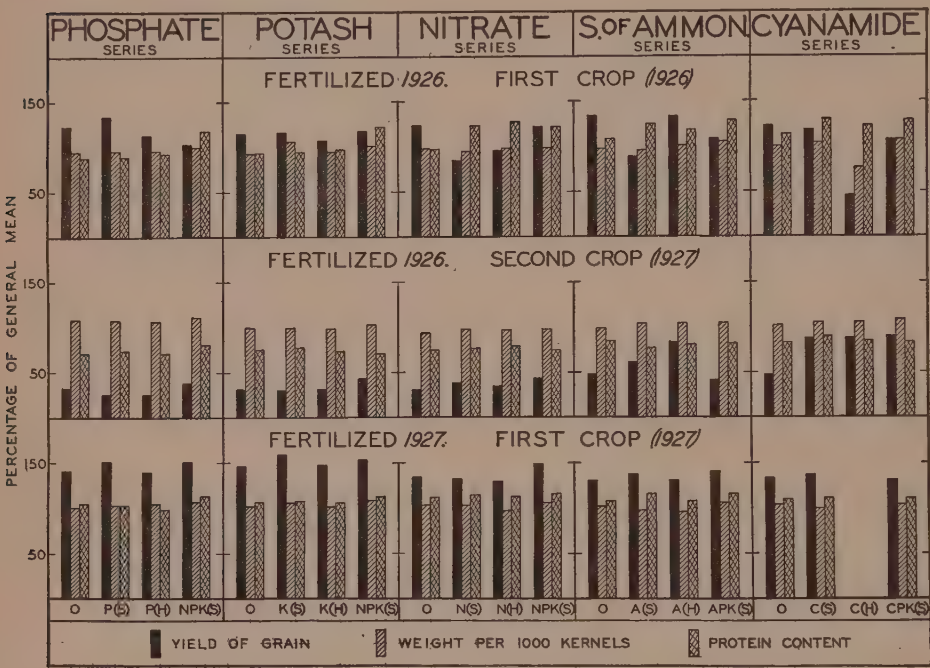

FIG. 2. *Relative effect of fertilizers on yield, weight per 1,000 kernels and protein content of grain. O—unfertilized. S—fertilized at seeding. H—fertilized at time of heading.*

Variations in weight per measured bushel were somewhat irregular, but phosphate, ammonium sulphate and cyanamide at seeding each caused a reduction of about 2% in the season of application.

Ash content of the grain was determined in 1926 only. Phosphate applied at seeding to the summerfallowed plots increased, and nitrate at seeding diminished the proportion of ash constituents.

The coefficient of mealiness (4) of the grain produced was reduced by all the nitrogenous fertilizers (nitrate, sulphate of ammonia and cyanamide) in 1926, whether they were applied singly at seeding or at heading, or in combination with phosphate and potash at seeding. In 1927, on the other hand, no significant differences were evident in either the summerfallowed plots fertilized in that season or the stubble series.

DISCUSSION

It may reasonably be concluded from the foregoing results that under soil and weather conditions similar to those of this experiment, even heavy top-dressings of fertilizers will have relatively small and uncertain effects

on the yield of barley from summerfallowed land. The experiments of Ellis (2) with wheat, however, suggest the possibility of greater responses from the more recent method of drilling-in moderate amounts below the seed, introduced into Western Canada in 1928.

Russel and Bishop (7) point out that the long-continued experiments at Rothamsted, England demonstrate that under conditions of soil depletion there may be notable responses to both nitrogen and phosphate, and that when the requirements with respect to these elements are met, lowering of the nitrogen content of the grain may be effected by the presence of sufficient potassium. Experiments under English agricultural conditions however showed nitrogen to be the only one of these three fertilizer elements consistently effective in increasing yields. Moderate applications were found not to augment the nitrogen content of the grain to any practical extent, but heavier dosages increased the nitrogen content (a result which, although advantageous in feed grain, is not desired in malting barley) and in addition were less efficient in promoting yield. Moreover, it was found that these increases in nitrogen content could not be offset by phosphate or potassium as on the depleted Hoosfield soil.

In Western Canada, cereal production on well prepared summerfallow is determined largely by weather conditions, particularly by the amount and distribution of precipitation. It is perhaps not surprising therefore to find that in these circumstances additional top-dressings of nitrogen are not advantageous and may be in some respects detrimental, agronomically through lodging and from the standpoint of Canadian maltsters by increasing the nitrogen content. Stubble land however may be expected to be relatively deficient in available nitrogen, and it is interesting to note that the presumably moderate amounts of nitrogen carried over for the stubble crop increased the yield of grain without increasing the nitrogen content, a result which is characteristic of nitrogen-deficient soils in other regions (1, 6, 7, 8). The amounts actually carried over being unknown, comparisons cannot be made with English experience or with the results of Richardson and Gurney (6) who found that at the Waite Institute in South Australia there was a quantitative relation, in accordance with the law of diminishing returns, between the amount of sulphate of ammonia applied and the yield of barley, and that the percentage of nitrogen in the grain was practically unaltered by dressings ranging from nil to 56 lb., whereas with dressings of more than 1 cwt. per acre there was a material increase in nitrogen content which reduced the quality of the grain for malting purposes. Nevertheless, the indications that nitrogenous fertilizers may improve the yield without increasing the nitrogen content of barley grown on stubble land are probably the most interesting feature of the present experiments. They suggest the desirability of further trials to ascertain whether economic yields of low-nitrogen barley could not be secured, in districts of sufficient rainfall, from stubble land moderately fertilized.

The increased weight and volume per 1000 kernels due to phosphate and potash are in accordance with the available information (largely European) respecting the effects of these substances on the fruiting parts of plants, reviewed by Hartwell (5). Large kernels are preferred by the maltster, but further experiments would be required to determine whether

any appreciable increase in size results from more moderate but economically practicable applications. The effect of the residual nitrogen fertilizers on the weight and volume per 1000 kernels of grain from the stubble plots is also paralleled by European observation, it having been noted that on nitrogen-deficient soils, applied nitrogen up to the normal needs of the crop may increase the size and specific gravity of cereal grains, but that additional amounts delay tillering, thus increasing the proportion of undeveloped kernels and reducing the average size (5).

SUMMARY

Field experiments conducted at Manitoba Agricultural College in 1926 and 1927 indicated that the yield of barley from summerfallowed land was unlikely to be materially increased by top-dressings of phosphatic, potassic or nitrogenous fertilizers, even if applied in large amounts. The addition of nitrogen may in some seasons result in lodging of the crop and also increase the nitrogen content of the grain (the latter being undesirable from the standpoint of the Canadian maltster). Phosphate and potash increased the average size and weight of kernels, but it remains to be determined whether such effects would be forthcoming from economically practicable amounts of these fertilizers.

On stubble land in 1927, the residual increments of nitrogen remaining from the previous year's fertilizing resulted in marked increases in the yield of grain unaccompanied by any corresponding increase in protein content, and some improvement in weight and volume per 1000 kernels, suggesting that in districts of sufficient rainfall, economic yields of low-nitrogen barley might be secured from stubble land by the addition of moderate amounts of fertilizers. This point would seem to merit further investigation.

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Résumé

L'effet des engrais chimiques sur le rendement de l'orge du Manitoba et sur la la valeur pour le maltage. J. W. Hopkins, Laboratoire national de recherches, Ottawa, Ont.

Des essais en grande culture conduits au collège d'agriculture du Manitoba en 1926 et 1927, ont indiqué que les applications en couverture d'engrais phosphatés, potassiques ou azotés, même considérables, n'exercent que peu d'effet sur le rendement de l'orge cultivée sur jachère. L'apport d'azote peut faire verser la récolte en certaines saisons et accroître la proportion d'azote dans le grain. (C'est là un résultat qui n'est pas à désirer au point de vue des malteurs canadiens). La phosphate et la potasse ont augmenté la grosseur moyenne et le poids des grains, mais il reste à voir si l'on obtiendrait ces effets au moyen de quantités pratiques et économiques de ces engrais. Sur chaume, en 1927, les résidus d'azote restant des engrais chimiques appliqués l'année précédente, ont provoqué une augmentation marquée dans le rendement du grain, mais non accompagnée d'une augmentaion correspondante dans la teneur en protéine, ainsi qu'une certaine amélioration du poids et du volume par 1,000 grains, ce qui donne à croire que dans les districts où la pluie est suffisante, on pourrait obtenir des rendements économiques d'orge faible en azote en appliquant des quantités modérées d'engrais chimiques. C'est là un point qui mériterait d'être étudié plus à fond.

REPORT OF THE VARIETY ZONE CO-ORDINATION COMMITTEE OF THE WESTERN CANADIAN SOCIETY OF AGRONOMY[1]

The Variety Zone Co-ordination Committee was formed at the Edmonton meeting of the Western Canadian Society of Agronomy in 1929 for the purpose of co-ordinating the cereal variety zones of the Prairie Provinces, with respect to the designations of the zones and the location of their boundaries. The committee is composed as follows: Dr. J. B. Harrington *(Chairman)*, University of Saskatchewan, Saskatoon, Saskatchewan; Mr. W. J. Breakey, Dominion Experimental Farm, Morden, Manitoba; Mr. J. G. Davidson, Dominion Experimental Farm, Indian Head, Saskatchewan; Dr. C. H. Goulden, Dominion Rust Research Laboratory, Winnipeg, Manitoba; Mr. W. D. Hay, Dominion Experimental Farm, Lethbridge, Alberta; Dr. K. W. Neatby, University of Alberta, Edmonton, Alberta.

The 1932 report of the committee was published in *Scientific Agriculture*, 13 : 473–475, March, 1933, and shows on page 474 a map of the Prairie Provinces in which the cereal zones of the three provinces were co-ordinated at the provincial boundaries, but not yet co-ordinated as to designations of zones. At Edmonton, in 1935, the committee was able to announce co-ordination as to both boundaries and designations, but there still existed within the different provinces some lack of similarity as to the basis upon which to constitute cereal zones. They were all more or less on a soil-climatic basis, with exceptions as in the case of southeastern Saskatchewan.

Early in 1936, the agronomists of Saskatchewan and Alberta took the further step of placing their cereal zones fully on a soil-climatic basis. This was in accord with the previous action of the Manitoba agronomists. The matter of keeping the zone boundaries co-ordinated was a simple matter. It was decided recently by the Saskatchewan and Alberta cereal committees that the zones should be numbered 1, 2, 3 and 4, the numbers referring to: (1) the light brown, short grass, treeless prairie, (2) the dark brown treeless prairie, (3) the aspen grove and northern black soils, and (4) the wooded and grey forests soils.

The Saskatchewan Cereal Committee found it advisable to subdivide the main soil-climatic zones to facilitate cereal variety recommendations and they adopted the method of designating the sub-zones by letters following the zone numbers. The Alberta Cereal Committee did not disagree with this plan but found no need of using sub-divisions at the present time. The Manitoba Cereal Committee will not have its 1936 meeting until fall and, therefore, has not made definite pronouncements as to the use of the sub-zone designations. However, the matter of zone designations was taken up with a number of members of the Manitoba Committee thoroughly by correspondence and they were wholeheartedly in favour of the use of the method adopted in Saskatchewan. They suggested that a presentation of the co-ordinated zone map for the three provinces might well tentatively show the Manitoba zones as they will appear if fully co-ordinated with the Saskatchewan zone designations. The committee, therefore, presents the accompanying chart which shows

[1] As given at the Annual Meeting of the Western Canadian Society of Agronomy on June 21, 1936, at Swift Current, Saskatchewan.

SOIL-CLIMATIC ZONES OF THE PRAIRIE PROVINCES

As Adapted for Cereal Variety Recommendations.

Co-ordination of the Zone Boundaries and Designations Effected by the Variety Zone Co-ordination Committee of the Western Canadian Society of Agronomy.

the co-ordinated zone map as adopted in Alberta and Saskatchewan and likely to be adopted in Manitoba. (NOTE: The Manitoba Agronomists adopted these designations and boundaries at the annual meeting in December, 1936.)

The co-ordination committee feel that this map, culminating as it does some eight years of zone evolution, is a thing of much value. It is felt that the adoption of the natural soil-climatic zones is a sound basis not only for cereal variety recommendations but also for recommendations concerning most other aspects of Western Agriculture. For several years the agrostologists have used a soil zone map as their basic consideration. In 1936, the Saskatchewan Weed and Farm Machinery Committees adopted the soil-climatic zones as fundamental in discussions of recommendations. There is little question but that recommendations as to farm procedure and management must have the soil-climatic zones as their foundation. The co-ordination committee believe that the more thoroughly the western agriculturist understands the characteristics of and differences between the soil-climatic zones, the more intelligently he will be able to choose crop varieties and decide how to handle the other aspects of his farm business.

The present variety zone map is a good example of friendly co-operative achievement. It is not a finished product. Undoubtedly the evolution will proceed further. Problems of co-ordination will arise, as in the past, but there is every indication that they will be solved easily and satisfactorily, as in the past. The committee wishes to express here its sincere appreciation of the wholehearted support it has had from the agronomists of the three provinces in its work of co-ordination during the past eight years.

J. B. HARRINGTON,
Professor of Field Husbandry,
University of Saskatchewan.

June 21, 1936.

Discussion Respecting the Co-ordination of Cereal Variety Recommendations, in Connection with the June, 1936, Report of the Variety Zone Co-ordination Committee of the Western Canadian Society of Agronomy.[3]

From the viewpoint of an interprovincial co-ordinating committee, the closest possible amount of agreement in varietal recommendations is desirable. It is not easy, however, to define agreement in the matter of varietal recommendations. It is obviously unreasonable to expect each province to recommend the same varieties. Conditions vary a great deal from Morden to Beaver Lodge and from Lethbridge to Melfort, and varieties must be recommended according to their performance in the different soil-climatic zones and according to their resistance to the natural enemies which are likely to infest given areas.

This means that while some varieties of wide adaptation may be recommended in parts of all three provinces, most varieties will only warrant recommendations in one, or perhaps two, of the provinces. The provincial cereal committees are the proper authorities for drawing up the varietal recommendations for the different provinces. In a case where a recommendation of one province profoundly differs

[3] Discussion revised January 6, 1936.

from the recommendations of an adjacent province with respect to similar soil-climatic zones adjacent at the provincial boundary, the co-ordinating committee can probably assist in helping the two provincial committees concerned to remedy the inconsistency.

Varietal recommendations in the Prairie Provinces have, in the past, agreed fairly well and, on the whole, they show reasonably satisfactory co-ordination at the present time. Considering wheat first, during the past few years the Manitoba cerealists have recommended Ceres, Reward and Mindum for the areas of Manitoba next to Saskatchewan. The Saskatchewan recommendations for the areas next to Manitoba were Ceres, Reward and Marquis. Considering the greater rust hazard in Manitoba, it is to be expected that the moderately resistant durum, Mindum, would be recommended in place of Marquis. The situation at the Alberta-Saskatchewan boundary has also been logical. Marquis has been recommended on both sides. In eastern Alberta, Red Bobs strains have been recommended, while in Saskatchewan they have not, but considering the greater rust hazard in Saskatchewan and the high susceptibility of the Red Bobs strains, this difference is quite reasonable. Garnet is recommended in the shorter season zones in Alberta, but not far east of Edmonton nor in Saskatchewan where the frost hazard is less.

A few months ago, Reliance was recommended for Zone 1 in Saskatchewan and Thatcher was recommended for most other parts of the province. In accord with this action there is the recent recommendation of Canus in Zone 1 of Alberta and of Thatcher in Manitoba. Canus is a variety having the same parentage as Reliance and resembling Reliance in its ability to resist drought and yield well. Thatcher, on account of its high rust resistance and yielding capacity suits Manitoba and the eastern half of Saskatchewan particularly well.

In oats, the situation is satisfactory. Banner and Victory are the principal varieties recommended in each of the three provinces. In Manitoba and eastern Saskatchewan where the rust hazard is great, the resistant variety Anthony is recommended. Where earliness of maturity is desired Gopher is recommended in Saskatchewan, and Legacy and Alaska in Alberta. These three varieties do not differ very significantly and none of them are recommended for Zone 1, the dry short grass prairie region, which includes much of the interprovincial boundary. The difference in the oat recommendations, therefore, can hardly be considered important.

The barley situation is also quite logical. In the most favourable barley growing districts of the West, the malting Barley O.A.C. 21 is recommended in each province. For feed use, the variety Trebi is recommended in each province. Hannchen is well suited to the drier parts of the West and is recommended in Alberta and Saskatchewan. The smooth-awn variety, Regal, is recommended in all zones of Saskatchewan. In Alberta another smooth-awn variety named Newal is recommended in all zones and Regal is recommended for Zones 1 and 2. In general value, the two varieties are similar but their adaptation differs somewhat. In Manitoba the smooth-awned variety Wisconsin 38 is recommended in all zones. This variety appears to be better adapted to Manitoba conditions than Regal and Newal.

In the minor crops, flax and rye, the situation is satisfactory and the details as to the varieties recommended need not be gone into here.

In conclusion, I feel that the matter of varietal recommendations is being taken care of reasonably satisfactorily and that in case of need, the co-ordination committee is in a good position to function with respect to the maintenance of consistency in the recommendations.

J. B. Harrington, Chairman,
W.C.S.A. Variety Zone
Co-ordination Committee.

Saskatoon, Sask.,
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CONTROL OF POTATO FLEA BEETLES

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On August 20, 1936, an informative test was conducted on a small area of tomato plants to determine the effect of Cubor dust "75" (.75% rotenone) and derris-gypsum dust (.4% rotenone) on the control of the potato flea beetles *(Epitrix cucumeris*, Harris*)*, which were present in exceptionally large numbers. The dusts were applied around 6.00 o'clock at night and within an hour the ground was thickly dotted with wriggling beetles. These were all dead the following morning.

On August 22 the patch was examined and no live flea beetles were found on the plants. Small areas one inch square were marked off on the ground below the plants and counts made of dead insects. From 0 to 12 flea beetles were found per square inch as well as an occasional aphis, potato beetle and lady bird beetle. The control of these insects appeared to be practically complete at the time of examination.

Ten days after this application the tomato plants were found to have occasional leaflets with 3 to 5 flea beetles present and feeding.

An adjacent unsprayed plot of potatoes was found to have from 0 to 19 flea beetles per leaflet actively feeding. These were given one application of 12–8–80 copper-arsenate lime dust on August 25 and a few days after treatment re-examined. The flea beetles were still present and feeding.

As the potato foliage was still healthy on the area undug on September 8, a further examination for flea beetles was made and from 0 to 24 beetles per leaflet were found. The tomato vines on this date showed only the odd beetle, a remarkable illustration of the two methods of treatment.

The progress of the flea beetles through the potato plantings to the tomatoes was interesting. As the potatoes were dug, the infestation kept moving to the undisturbed plants in a uniform manner and while there were beetles present throughout the whole area, severe infestation and definite foliage injury always occurred uniformly along the entire rows from the edge of the plantings inward, rather than in spasmodic patches.

Identification of the dead flea beetles showed the striped cabbage flea beetle, *Phyllotreta vittata* Fabr., present in small numbers.

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